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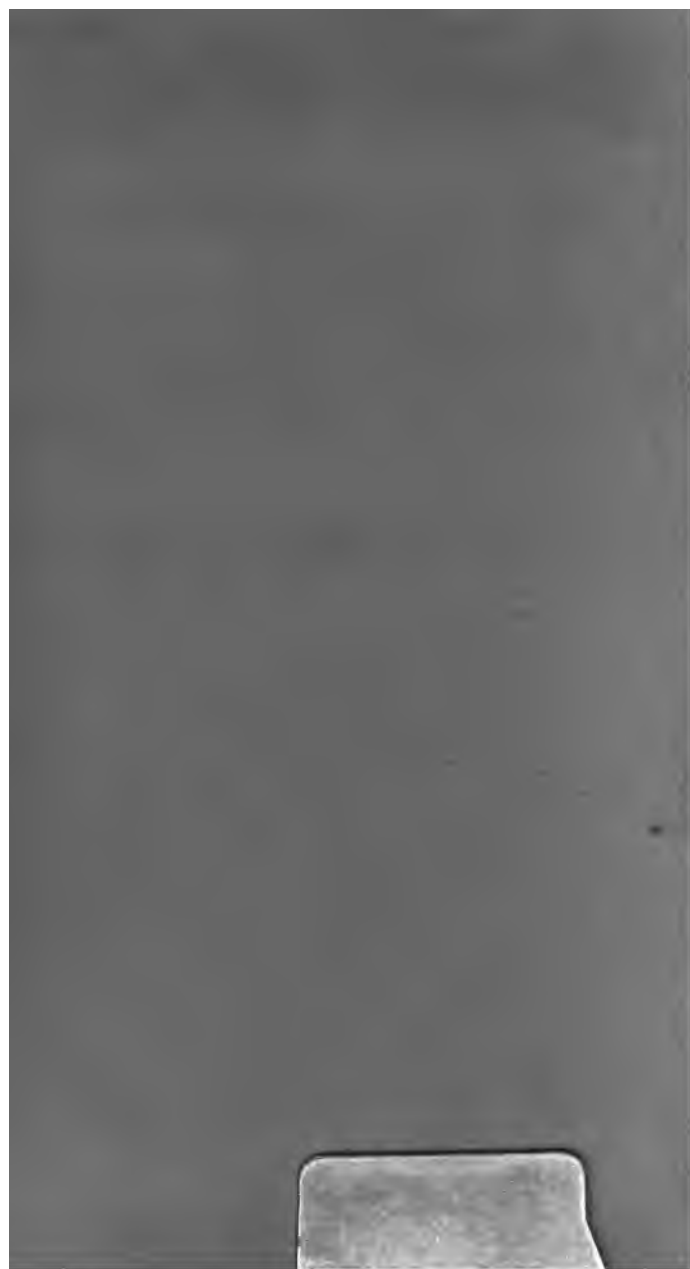
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ANIMALS
OF
THE FARM

HODGES





OUTLINES
OF THE
STRUCTURE AND PHYSIOLOGY
OF
THE ANIMALS OF THE FARM,
FOR
AGRICULTURAL STUDENTS AND FARMERS.

BY
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TO
THOMAS KIRKPATRICK, ESQ., M.D.,
HEAD AGRICULTURAL INSPECTOR;
AND TO THE
PUPILS OF THE ALBERT AGRICULTURAL SCHOOL OF
THE NATIONAL BOARD, GLASNEVIN.

THE kind reception which has attended previous attempts to render the facts of agricultural science accessible to the young farmer, and the adoption of the "Lessons in Chemistry and its Application to Agriculture," and of the "First Steps to Chemistry," in the schools of the National Board of Education, and in many public and private academical establishments, both in this country and in England, Scotland, and America, have encouraged me to prepare this little book to serve as an introduction to the study of the Structure and Physiology of the Animals of the Farm. Its contents are chiefly derived from the lectures which I have delivered before the pupils of the Albert Farm, Glasnevin, in connexion with the National Board. The interest which I found excited by these lectures, induces me to hope, that in the present form the information which it attempts to convey may be found useful and acceptable to all classes of agriculturists. I dedicate it to my friend Dr. Kirkpatrick, in acknowledgment of his zealous efforts in the cause of Agricultural Education, and to the Pupils of the Albert Farm, in testimony of the earnest desire for obtaining professional knowledge by which I have, on all occasions, found them to be distinguished.

JOHN F. HODGES.

QUEEN'S COLLEGE, BELFAST,
August, 1862.

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THE ANIMALS OF THE FARM.

PART I.

INTRODUCTORY.

THE object of the following chapters is to present the agricultural student with a series of outlines of the Structure and Physiology of the Animals of the Farm. The study of the interesting and curious processes by which the inanimate materials collected from the soil and the air by the labours of the plants grown in our fields, are converted into the substance of the living animal, and of the means by which these materials may be most economically and profitably employed, so as to secure its most perfect development—to give to the horse firm and active muscle, to the milch cow an abundant secretion of rich milk, and rapidly to cover the fattening animal with a heavy weight of succulent flesh—must, at all times, be full of interest even to those not engaged in agricultural pursuits.

As contributing to the extension of other branches of agriculture, as giving manure for plants and food for man, the Animals of the Farm, at the present time, properly attract a large share of the attention of enlightened agriculturists in every part of the world. The improvements which have been introduced into this department of husbandry, and the influence which these exercise upon the condition of the entire community, also materially interest the statesman, as well as the agriculturist.

The value of the cattle of the farm as the source of one of the most substantial articles of human food, is at present occupying the anxious consideration of several European countries, from the influence which its too limited supply is regarded as exercising on the physical develop-

ment of the people. It is justly considered that the insufficient amount of animal food which enters into the dietary of the great mass of the population, exerts a most deteriorating influence upon their condition, and thoughtful men in France, and several Continental States, have been induced to urge upon the farmers the propriety of diminishing the extent of the expensive, and—even under the more favourable circumstances of those countries—frequently hazardous cultivation of grain crops, and to increase the culture of roots, and thus to enable them to feed a greater number of animals, and to lower the price of meat, so as to render it more accessible to all classes.

The moist and temperate climate of Ireland, and the soils of this island, naturally so productive of tender and succulent herbage, are admirably adapted to the perfect development of the best breeds of cattle ; and even in districts where no extensive natural pastures now exist, it is possible, in this country so favourable to the growth of roots, by adopting the rules of improved agriculture, greatly to increase the annual produce of animal food, and thus contribute to the advancement of agriculture, and convert into nutritious products the largest possible amount of the materials of the earth, and also provide the means for its continued fertility. “You may judge,” remarks Boussingault, “the farmer of Bechelbronn,” one of the most distinguished of the agricultural chemists of Europe, “of the state of agriculture in a country by the attention which its farmers give to the preservation of manure ;” so also may we fairly regard the possession of numerous flocks of good cattle, now, even as it was in the days of the patriarchs—whose wealth we are told was “in cattle”—as a sure sign of agricultural prosperity.

In our survey of the *Animals of the Farm* we shall adopt the following arrangement, and consider—

1. The nature of the materials of which animals are composed—the raw material of the animal fabric.
2. The peculiar forms or structures into which these materials are converted in the bodies of animals.
3. The solid framework of the animal.
4. The arrangements by which the health of the animal is maintained—digestion—the circulation of the blood—respiration.

5. The circumstances which influence the production of the various parts of the animal body.

6. The relative value in feeding of the crops usually grown by the farmer.

7. The treatment of the chief departures from health, or the diseases to which the Animals of the Farm are liable.

PART II.

CLASSIFICATION OF THE ANIMAL KINGDOM.

IN proceeding to the investigation of the animal body, we may, by mechanical means—by dissection—separate its various structures, just as the engineer who, in the examination of a complicated machine, such as the steam-engine, removes its screws and takes asunder the pieces which compose it, so as to study their forms and adjustments. The student of the animal machine, with his dissecting knife, removes its coverings, and traces the course of its tubes and the forms of its solid framework, and examines the mechanism of its joints and the arrangements of the bands and pulleys by which the movements of its limbs are regulated; and to assist him in his scrutiny of the parts which are too minute to be fully explored by the unaided sight, he makes use of the microscope. The branch of science which occupies itself with these investigations is termed **ANATOMY**, from the Greek word *anatemno*, and **COMPARATIVE ANATOMY** when its inquiries are not confined to the human body, but embrace all the various tribes of animals.

A mere survey, however, of the form and arrangements of the animal body would not be sufficient for the practical objects contemplated in these Outlines. How do the various parts of which the machine is composed act, and by what means is their fitness for their work maintained? are questions intimately connected with the investigation of the living animal. The study of these actions or *functions* of the animal machine, which are characteristic of the living animal, belongs to another department of science, termed

PHYSIOLOGY, or the science of life, and we shall require, in our observations, to employ the facts which have been accumulated in both of these branches of knowledge. Anatomy will give us descriptions of the peculiarities of the various parts which compose the bodies of the Animals of the Farm; while Physiology will explain to us the work which they perform, and the means by which their healthy action is maintained.

From the time of Aristotle, the Greek philosopher, who is regarded as the father of natural history, numerous attempts have been made to form such an arrangement or classification of the vast domain of the animal kingdom as would enable the student to group together into natural divisions its countless tribes of inhabitants, and thus facilitate his investigations of their distinguishing peculiarities. It was reserved for a distinguished French philosopher, Baron Cuvier, whose researches into the structural peculiarities and internal economy of animals suggested to him the proper basis for their arrangement, to lay the foundation of that natural system of classification, which, with some modifications, is now generally adopted.

According to this system, the animal kingdom, for purposes of classification, is divided into five great groups or departments, termed—

- 1st. The department of VERTEBRATA (*verto*, Latin, *I turn*), including the animals which are furnished with a back-bone and an internal skeleton or bony framework, to which soft fleshy bands, termed muscles, are attached.*

* The characters which distinguish the vertebrate animals are concisely stated as follows, by our English Cuvier, Professor Owen—"The principal mass of the nervous system is disposed in a median axis, consisting of the brain and spinal cord, situated in the dorsal aspect of the body behind the heart and digestive system, and inclosed in a bony or cartilaginous case, constituting a vertebral column. The organs of the five senses—sight, hearing, smell, taste, and touch, are almost always present. The respiratory organs communicate with the pharynx, or anterior part of the alimentary canal. The mouth opens in a direction parallel with the axis of the body, and is provided with two jaws, placed one above or in front of the other. The blood is red. The heart is a compact muscular organ, having never fewer than two cavities, an auricle and ventricle. The muscles surround the bony or gristly levers on which they act, or in other words, the skeleton is *internal*. The locomotive members never exceed two pairs. The sexes *are distinct*."

- 2nd. The department of **ARTICULATA** (*articulus*, Latin, *a joint*), including animals composed of rings or joints, like crabs and insects.
- 3rd. The department of **MOLLUSCA** (*mollis*, Latin, *soft*), including the animals which, like the snail and whelk, are destitute of an internal skeleton, and which are in many cases covered with a shell.
- 4th. The department of **RADIATA** (*radius*, Latin, *a ray*), including animals which, like the star-fish and sea-urchin, have the organs of sense and motion arranged round a central axis.
- 5th. The department of **PROTOZOA** (Greek, *proton*, first, and *zoon*, animal), in which are placed the microscopic animals called *Infusoria*. These are regarded as representing the most simple forms of animal life.

The animals which have been grouped together in each of these great departments possess certain common characters, but, nevertheless, exhibit well-marked differences; hence it has been found convenient to subdivide the groups into *classes*; thus some of the vertebrata (backboned animals) are distinguished by the possession of special organs for the supply of nourishment to their young (*mammæ*, teats); others are characterised by certain differences in the structure of their organs of respiration, and in the qualities of the blood which circulates in their vessels. Availing himself of these natural distinctions, the naturalist divides the vertebrated animals into five classes, viz., *mammals*, *birds*, *reptiles*, *amphibia*, and *fishes*. These classes are still further subdivided, according to certain peculiarities in their structure and mode of life, into divisions termed *orders*. Thus the first class, or mammals (teat-bearing animals), is subdivided into twelve orders, to which the following technical names are given:—

- Order 1. **BIMANA** (Lat. *bis*, two; *manus*, a hand) of which the only example is man.
2. **QUADRUNANA** (Lat. *quatuor*, four; *manus*, a hand); which includes the monkeys, apes, and baboons.
3. **CHEIROPTERA** (Greek, *cheir*, a hand, *pteron*; a wing); example the bat.

4. INSECTIVORA (Lat. *insecta*, insects ; *voro*, I devour) ; which contains the mole and the hedgehog.
5. CARNIVORA (Lat. *caro*, flesh ; and *voro*, I devour) ; to which the dog, wolf, and bear belong.
6. CETACEA (Greek, *Ketos*, a whale) ; which contain the whale and the porpoise.
7. PACHYDERMATA (Greek, *pachus*, thick ; *derma*, a skin) ; of which the horse, ass, and pig, are familiar examples.
8. RUMINANTIA (Lat. *rumino*, I chew the cud) ; includes animals which ruminate, like the ox, goat, and sheep.
9. EDENTATA (Lat. *ex*, without, and *dens*, a tooth) ; animals destitute of teeth in the front of their jaws. The sloth belongs to this order.
10. RODENTIA (Lat. *rodens*, gnawing) ; the animals placed in this order are destitute of dog-teeth, but are distinguished by two large incisors (cutting-teeth, Lat. *incido*, I cut). The mouse, hare, and rabbit, are familiar examples.
11. MARSUPIALIA (Lat. *marsupium*, a purse) ; example, the kangaroo.
12. MONOTREMATA (Greek, *monos*, one ; and *trema*, orifice, from the orifices of the urinary, genital, and alimentary canals opening, as in birds, into a common pouch, *cloaca*, which includes only three species, natives of Australia) ; the ornithorhynchus or duck-billed platypus, is the most familiar example.

Such are the divisions of the great class of teat-bearing animals usually adopted by writers on Natural History. It includes many animals but little known to the greater number of our readers ; but it is interesting to us, as numbering among its members the biped, Man, whose organs of locomotion, though consisting of only a pair of limbs, raise him above all other animals ; and also the hair-covered quadrupeds. Our attention is merely required to the 1st, 7th and 8th orders—viz., Man, and the thick-skinned and ruminating animals which he has rendered subject to his will, and made to supply his wants. The Ani-

mals of the Farm, you are aware, present certain characteristic differences in the structure of their limbs, by which they are distinguished from the dog and other carnivorous (flesh-eating) animals, the extremities of their toes—or, rather, of one of the toes, which is alone fully developed—being enclosed in a dense horny case, or hoof. All hoofed animals are essentially grass-eaters, while the carnivorous dog, and the other members of his order, have flexible fingers and toes, armed on their upper surface with claws to serve as instruments for seizing their prey.

The animals which form the peculiar objects of the farmer's care, are distinguished by such well-marked characters, that in entering upon the study of this special department of natural history we do not require, like the naturalist, who includes in his survey the whole vast extent of the animal kingdom, to point out the fundamental distinctions which enable him, though occasionally with considerable hesitation, in his judgment to assign some of the simpler forms of organic life their appropriate place in his classification. The student is aware that there are many forms of organization which, though commonly classed among animals, exhibit very few of the characters which are regarded as distinguishing the animal from the vegetable. The common sponge, which the farmer who resides on the sea-coasts occasionally finds adhering to a stalk of sea-weed, presents us with a familiar example of these forms of life which used to puzzle naturalists, and was at one time supposed to be a plant. It is utterly destitute of feeling, it may be saturated with the strongest acids of the chemist, and may even be burnt without exhibiting any evidence of sensibility, while the sensitive plant of our botanic gardens, as is well known, shrinks from the slightest touch. Thus the concise axiom of the celebrated Linnæus, that stones grow, vegetables grow and live, animals grow, live, and feel, would force us to place the sensitive plant, which collapses its leaflets at the slightest shock, among animals, while the impassible sponge would be classed with vegetables. We cannot, indeed, except by arbitrary and artificial divisions, establish any chemical or physical distinction between the lower forms of animal and vegetable life. There is no natural division, they are merely

“specialized members of one and the same group of organized beings.”

Both the plant and the animal, however, exhibit many characters in common. The plant, like the animal, appropriates nourishment for its development and support, and for the production of new individuals of its kind; but the animal alone possesses the power of moving about from place to place. In the chemical composition of the plant and the animal we also recognise considerable difference, not, indeed, in the nature of the materials of which they are formed, but in the proportions in which these materials are employed in their structure. The chemist has made us acquainted with sixty simple or elementary forms of matter as composing all the materials both of the solid earth and of its plants and animals, yet of these so-called simple substances not more than seventeen are known as constituting the structure both of plants and animals. The labour, therefore, of acquiring a knowledge of the crude building materials which, under the influence of life, are moulded into the bodies of our horses, cows, sheep, and pigs, is greatly diminished. Nor are these simple building substances selected from those elementary bodies which are but little known to the common observer. The greater number of them are familiar to every person, as they enter into the production of compounds, that is, of substances formed by their union, which are employed in our manufactories or found in the manures sold to the farmer. The names of these elements are *Oxygen, Carbon, Nitrogen, Hydrogen, Calcium, Phosphorus, Sulphur, Magnesium, Chlorine, Iodine, Bromine, Fluorine, Potassium, Sodium, Iron, Manganese, Silicium*. COPPER is found in the blood of many of the invertebrated animals, molluscs, &c., but is not a normal constituent of the bodies of the vertebrata. BROMINE also has been discovered only in a mollusc, the *janthina violacea*. Though only two or three of these elementary bodies are met with in nature in their simple forms, yet everywhere around us, in the soil, in the water, and in the air, we find compounds which have been formed by their union.

Both plants and animals are characterised by being composed of different parts or organs (from the Greek word *organon*, an instrument), to which, in the living plant or animal, *special offices*, or what are usually termed “functions,”

are assigned. Thus the eye and the stomach are organs of the animal body; the function of the former is sight, and that of the latter to digest the food. By the processes of the chemist we can effect what is termed the *ultimate analysis* of these organic structures, so as to separate them into the simple elementary particles, of which science has discovered all the various bodies in nature, both organic and inorganic, however different in form or appearance, to be composed. Before, however, these raw materials of organic nature are moulded into the structures of plants or animals, they unite to form an intermediate class of compounds, destitute of any mechanical regularity in the arrangement of their particles. To these substances the name of PROXIMATE PRINCIPLES or *organic compounds* has been applied. Starch, gum, albumen, and various other substances which have been described to you as constituents of plants, you will recollect, afford examples of the organic compounds produced by vegetables. When we examine the chemical composition of the bodies of animals we can distinguish three classes of compounds as forming the various structures of which they consist, in substances containing nitrogen as an essential ingredient, substances destitute of nitrogen, and mineral compounds. So far the plant and the animal exhibit a resemblance. But when we investigate the proportions in which these three classes of compounds contribute to build up their structure, we find a marked difference. The bulk of the plant, as you are aware,* is composed chiefly of compounds such as cellulose, starch, &c., containing merely the elements carbon, oxygen, and hydrogen. It contains but a small amount of nitrogen. The tables which give the amount of ash or mineral matters that our crops leave when burned, also shew us how small is the proportion of mineral matters contributed by the earth to their developement. In the animal body, on the contrary, we discover that compounds containing nitrogen form the chief portion of its substance, and that mineral matters also are present in large amount. By considering the following approximate statement of the proportions in which the three classes of compounds contribute to build up the body of a horse of 4 years of age, you

* See the Author's "LESSONS IN CHEMISTRY for Farmers and Teachers," Chap. IV.

will be afforded a clearer idea of their relative amount in the structures of the Animals of the Farm :—

Constituents of the Horse	Bones & Cartilage	Blood	Flesh & Fluids	Total
Water, ...	8·67	150·50	440·29	559·26
Organic Combustible Matters,	24·26	36·94	154·70	215·91
Mineral Matters (Ash), ...	27·07	1·55	6·01	34·63
	60 lbs.	189 lbs.	601 lbs.	850 lbs.

Of the 215·91 lbs. of combustible matters of which the body of the animal consists, 188 lbs., or 86 per cent., contain nitrogen as an essential ingredient. None of these compounds, as we have said, exhibit any traces of organized structure, yet for their production the agency of beings possessing organs is necessary ; they are essentially products of organic life, and though chemistry now exhibits so many wonderful instances of control over natural operations, and has even been successful in forming certain compounds, such as *urea*, and the peculiar acid secreted by ants, *formic acid*, yet these have only been produced by acting upon other organic products. Neither the fibrin of the blood nor the starch of the plant has yet been artificially produced from its elements. To render more intelligible what we have just stated with respect to the *ultimate* and *proximate composition* of plants and animals, let us suppose a piece of flesh placed in the hands of the chemist ; he obtains from it, in the first instance, a substance possessing all the properties of fibrin, the proximate compound forming the chief bulk of the flesh. He continues his investigation by submitting the fibrin to various processes, by which it is resolved into certain proportions of oxygen, hydrogen, carbon, nitrogen, and sulphur ; these are the ultimate elements of the flesh.

In addition to the proximate principles which result from the union in the living organism of the simple elements, we also discover another class of compounds which are produced by the transformation or decomposition of the materials of the body. These are separated from the system by particular organs, and are termed *secondary organic*

compounds. We have samples of secondary organic compounds in the bile, which is a peculiar liquid separated or *secreted* by the liver, and in urea and uric acid, two compounds, rich in nitrogen, secreted by the kidneys, and in the peculiar kind of sugar found in milk. The following are the names of the most important of the substances which belong to the two classes of organic compounds:—

Albumen	Common to Plants and Animals.	Urea.
Fibrin		Uric Acid.
Casein		Organic constituents of bile.
Gelatin (in bones, tendons, and ligaments).		Pepsin of the gastric juice.
Syntonin, or fibrin of the muscles.		Sugar of Milk.
Chondrin (in cartilage).		Lactic acid.
Elain (in fat).		Glucose, or grape sugar (in the blood).
Stearin (in the hard fats, and especially round the kidneys in the <i>ruminantia</i>).		Inosite (muscle sugar).
Margarin (in fat).		Cellulose (in the brain and spinal cord).
Hæmatosin (colouring matter of blood).		Hippuric acid (in the urine of graminivorous animals).
Hæmato-crystallin (in the blood globules).		
Globulin (the nitrogenous principle of the crystalline lens of the eye).		

The organized structures of which all the parts, both of plants and animals, are composed, when examined by the

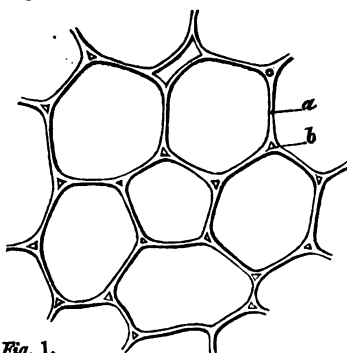


Fig. 1.

CELLULAR TISSUE OF VEGETABLES.

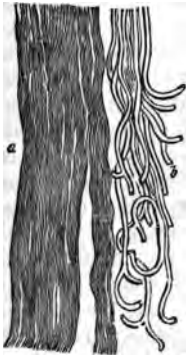
microscope in the early stages of their development, are found to be composed of little bags, technically termed *cells* (Lat. *cella*), the walls or envelopes of which are formed of a delicate transparent membrane; each cell contains within it a second minute cell (nucleus), and sometimes within that again a granular body (*nucleolus*). Such is the most simple form in

which organized structure is recognized, and the cell, such as we have described, is regarded as the primary rudimental form which organic matter assumes in building up the

framework both of plants and animals, and in some simple forms of vegetable life, such as the red snow, *Protococcus nivalis*, constitutes their entire organization.

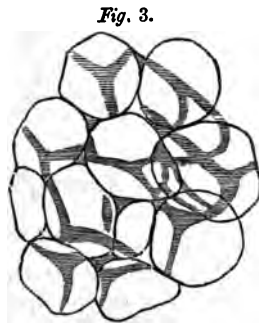
In plants, and in animals low in the scale of being, as the polyps (Greek, *polus*, many; *pous*, a foot), radiated animals, and in the embryonic state of the higher animals, the cellular structure may be detected in every part, but in the adult fully developed animal the simple cell is found to undergo various metamorphoses, and to be transformed into peculiar *tissues* or *textures*, as in the muscular, nervous, fibrous, and other structures of the animal body, in which its original form can no longer be discovered.

The proximate principles are all produced by the union of the ultimate elements—of the carbon, the oxygen, the hydrogen, the nitrogen, the phosphorus, and the sulphur, into which the chemist can resolve the albumen, the casein, and the fibrin of our wheat and our potatoes. By the combination of the proximate principles, again, the various textures of the animal body are produced; united into muscular tissue, they form the lean of beef and mutton; and, woven into the network of filaments, known as areolar tissue (Lat. *areola*, a vacant space), they bind together the organs of the animal machine. These organs are themselves made up of the tissues; and thus we may describe the body itself as capable of being resolved, by mechanical and chemical means, into *organs, tissues, proximate principles, and ultimate elements*.



a. White fibrous tissue.
b. Yellow do.

ANIMAL TISSUES.



Fat Vesicles.

Fig. 3.

Fig. 2.

No sooner does the previously dead and inactive organic matter become organized in the structures of the body of the animal than it assumes peculiar properties.

Some of these properties are exhibited by the textures both of the living and dead animal, and depend merely upon the physical arrangement and chemical composition of the tissue. Thus a piece of cartilage, or gristle, as it is commonly called, when separated from the body, does not lose its elasticity and flexibility, but the peculiar property of contracting or shortening its fibres, which muscle or flesh manifests in the living animal, is not retained by dead muscle.

Among the properties possessed by animal membranes, to which it is necessary that our attention should be directed from their important influence on many processes in the animal economy, is their permeability to liquids and gases. Thus it is found, in many diseases, that the watery particles of the blood transude through the walls of the vessel in which it is conveyed, so as to occasion swellings. In health, also, an escape of liquid in considerable quantity takes place from the walls of the vessels which are distributed to the lungs or organs of respiration, and from the skin. The property of animal textures to permit liquids to pass through them affords us a satisfactory explanation of various phenomena. It has been shown to depend upon certain physical laws, to which it is necessary that your attention should be directed. If a narrow glass tube, closed at one end with a piece of thin animal membrane, such as a piece of bladder, be partly filled with water, and placed in a vessel also containing water, the water in both the tube and the vessel being made to stand at the same level, no alteration in the level of the surface of the contents of either will take place; but if you add a few grains of common salt, or of any soluble salt, to the water in the tube, so as to increase its density, you will find, after a short time, that it will rise above the level of that in the glass. If, however, you were to add the salt to the liquid in the glass instead of to that in the tube, the alteration of the level will take place, but in a different direction; the liquid will sink in the tube and rise in the glass. If the tube and the glass contain saline solutions of different densities, the surface of the liquid

which possesses the greatest density will rise. Currents are thus established even through interposed membranes. When the tube contains some blood deprived of its fibrin, precisely the same thing occurs as with a solution of salt in water. The water of the glass is, as it were, drawn into the tube, and rises in it in opposition to the law of gravitation. When the tube is filled with an alkaline liquid, and placed in a vessel containing an acid solution, the alteration of the level of the liquids takes place with great rapidity, the acid contents of the glass flow towards the alkaline solution in the tube. In all these cases, however, the flow is not merely from the light to the dense liquid, or from the acid to the alkaline solution; a portion of the dense liquid penetrates through the membrane to that which possesses a less specific gravity, so that two currents are established, and a mutual interchange of particles takes place. To these curious physical phenomena the names of *endosmose* and *exosmose* were applied by Dutrochet, Professor of Chemistry in Jena (*endon*, inwards, and *osmos*, impulse; *ex* out, and *osmos*). These phenomena have lately been ably investigated by the Master of the Mint. We shall have occasion frequently to refer to them in explanation of many remarkable processes in the animal economy; you will therefore recollect that whenever two liquids of different densities are separated by an animal membrane an interchange will take place.

In the animal body we have, therefore, to use the words of Liebig in reference to this force, "All the conditions for rendering the circulating system, by means of the blood, a perfect suction-pump, which performs its duties without stop-cocks or valves, without mechanical power, nay, without regular canals or passages for the transmission of the fluids. The solution formed in the digestion of food in the stomach is *acid*; the blood is a *saline* and *alkaline* fluid. The whole digestive or intestinal canal is surrounded by a system of infinitely ramified blood vessels, in which the blood moves with great velocity. By means of the urinary apparatus, the water which has flowed into the blood is immediately filtered off, and the circulating fluid is thus kept in the same state of concentration."—*Familiar Letters*, 112.

PART III.

THE BLOOD.

“For the life of the flesh is the blood.”

IF you divide a stalk of grass with a knife you will observe that a watery liquid exudes from the wounded parts of the plant. If you prick any part of the skin which covers your body with a needle, a drop of red-coloured liquid follows the puncture. Both the plant and the animal, therefore, contain within their structures a liquid which appears to be distributed through every part of their substance. The student is familiar with the purposes which the liquid—the *sap*, as it is termed—contained in the cells of the plant, is made to serve, and is prepared to hear that that which we find distributed through every part of the animal body also contains the materials required for its nourishment. In the animal, this liquid is termed BLOOD, and is found to be conveyed through tubes, named blood-vessels, to every part of its structure. We shall again have occasion to consider the peculiar structure of these tubes; it will, however, be sufficient for our present object to state that they consist of three sets of conduits, along which the blood is impelled mainly by an impulse communicated by a central organ named the HEART. One set of these vessels which convey the blood from the heart being called *arteries* (Greek, *aer*, air; and *tereo*, I keep), while it is brought back to it again by a second set of vessels named *veins* (Lat. *venio*, I proceed); between the extremities of these vessels there exists a net-work of exceedingly minute hair-like vessels, termed *capillaries* (Lat. *capilla*, a hair). The blood which flows through these tubes is found to differ in colour; that contained in the arteries, which convey it from the central organ to the tissues, being of a bright red colour, while that which fills the veins has a dark purple colour.

In its fresh condition, as obtained by opening one of these tubes in the body of one of the higher animals, the blood is a reddish-coloured opaque liquid, heavier than

water, of a slightly saltish taste and peculiar odour. Its reaction is always alkaline. A drop of this apparently homogeneous liquid placed under the microscope is shown to be made up of two distinct portions, one of which consists of round, translucent, flattened, disc-like bodies, of a red colour, the *globules* or *corpuscles* of the blood, while the other portion is a liquid of a pale yellowish colour, which has been termed *liquor sanguinis*, in which the little globules swim. These globules are largest in the elephant, and smallest in the napu (musk deer). In all animals of the class mammalia, with the exception of the camel, dromedary, and llama, in which they are oval, the blood globules present the appearance of flattened discs, with a nearly circular outline, and exhibit a depression or dimple on both surfaces (see Fig. 4). They consist of a colourless investing membrane, and contain a fluid which is red by reflected, and yellow by transmitted light.

APPEARANCE OF THE BLOOD CORPUSCLES UNDER THE MICROSCOPE. A.—Oval blood corpuscles of the frog.

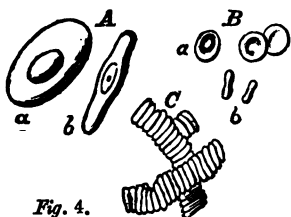


Fig. 4.

B.—Circular blood corpuscles of the mammalia.

C.—Human blood corpuscles, as frequently observed arranged in groups, presenting the appearance which a number of coins placed one on the top of the other would exhibit if the column which they formed had been partially overthrown.

In birds, reptiles, and most fishes, the discs present an oval shape, and a central nodule or elevation on both surfaces. Both the size and form, however, of the corpuscles, when the blood is withdrawn from the body, undergo alterations, depending upon the circumstances in which they are placed, as the little bags are elastic, and are readily swollen up, and rendered convex by liquids passing through their delicate walls, or shrivelled up by their contents exuding by osmotic action.

Very soon after the blood is withdrawn from the body of an animal it undergoes a change of appearance, which is termed coagulation, by which it becomes thick, and is gradually converted into a tremulous red jelly, which assumes the shape of the vessel in which it is received, and after

standing some time contracts to a firm red mass,—*the clot*,—while at the same time a clear yellowish-coloured liquid,—*the serum of the blood*,—is separated from it. The clot, when broken into pieces and examined, is found to consist of a net-work of fibres, between the meshes of which the *red globules* of the blood are held, and from which they may be removed by kneading the clot under a stream of water, precisely as the granules of starch, which give the white colour to a mass of dough, may be washed away. The matter which remains after washing the clot is an elastic substance of a dull white colour, and consists chiefly of the proximate compound, *fibrin*, which closely approaches in its composition to vegetable fibrin, such as we obtain from wheat flour. While *the serum* of the blood which exudes from the clot is found, when heated, and also when mixed with certain chemical agents, to consolidate or coagulate, and to possess all the properties of a solution of the proximate compound, *albumen*. When coagulated by heat, it forms a white opaque substance exactly resembling the white of an egg hardened by boiling. Fibrin exists in the *liquor sanguinis* in a dissolved condition, and is distinguished by its remarkable property of coagulating or separating in the form of fibres, when the liquids containing it are removed from the body. It is this property of fibrin that causes the coagulation of blood when abstracted from the vessels, and some beautiful experiments by Dr. Richardson, render it probable that fibrin is held in solution in the circulating blood by the agency of ammonia, one part of that substance being found sufficient to maintain the fluidity of 3000 parts of blood. He discovered that the volatile alkali escapes during the coagulation of blood, and that the solid clot is readily dissolved in serum rendered alkaline by ammonia. The matter which gives its red colour to the blood globules of the vertebrated animals is a peculiar colouring substance termed *hæmotosin* (Greek, *haima*, blood); it can be extracted by adding to the clot of blood a saturated solution of glauber salt, placing the mixture upon a filter, and washing with water, when the red matter will dissolve, and may be obtained as a brownish red mass by evaporating the solution. This colouring matter, when burned, leaves an ash, of which about 7 per cent. consists of iron.

The relations of hæmatosin to oxygen gas are exceedingly interesting and important, and have been compared to those exhibited by the colouring material indigo. Thus, indigo occurs in the leaves of the plant in a state which yields to water a yellow infusion. By exposure to the air this solution absorbs oxygen and acquires a blue tint. The oxygen, however, appears to be very loosely united with the pigment, and can readily be separated from it, and the pale yellow colour restored, and the change in its colour from yellow to blue, and from blue to yellow, may be repeated any number of times. So, also, the colouring material of the blood, by exposure to the action of oxygen in the lungs of animals, we shall find, changes its colour from an almost black hue to a bright vermilion. As it is conveyed through the body its oxygen gradually disappears, and in the capillaries it again recovers its dark colour, and this alteration of colour is continually taking place in its circuit through the body.

The delicate membrane which forms the wall of the little cells of the blood consists of a proximate compound, which has a composition closely approaching to that of albumen. The contents of the corpuscle consist of hæmatosin, which forms about 17 per cent. of the matters present,—of a crystallizable nitrogenous substance termed hæmato-crystallin,—and of fat, mineral matters, and water. The cells are nourished at the expense of the liquid in which they swim, and each cell, like the body itself, is in a state of change, the red cells being accompanied by white corpuscles, which many regard as the embryos of the red discs; and during the life of the animal new cells are continually coming into existence, advancing to maturity, and then becoming, like the other matters of the frame, unfit for the purposes of life; thus of the materials of the body it may be said that,

“ Having by degrees perfection won,
Restless, they soon untwist the web they spun.”

They attain their perfect form, and then are shrivelled up, and strained away from the circulating fluid. For every beat of the pulse (Draper) twenty millions of these organisms die.

As the blood is the reservoir from which the various materials for building up the structures of the body are *obtained, as required*, and also serves as the stream into

which the matters worn away are poured, so as to be separated from the system, it will be useful at the present stage of our survey to consider more closely the composition and properties of those proximate compounds which are found to be contained in it.

One thousand parts of blood contain from 60 to 70 parts of the proximate compound **ALBUMEN**. This substance exists in the serum of the blood and all the liquids of the body, and is believed to owe its solubility to the presence of an alkali. When the serum of the blood, or a solution in cold water of the white of an egg, is exposed to a heat between 140 and 150 degrees, the albumen which these liquids contain solidifies and is rendered, as when an egg is boiled, insoluble in water. The coagulation of albumen can also be produced by several chemical agents; thus the mineral acids (nitric acid, &c.), added to solutions containing it, discover its presence by rendering them opaque.* Albumen may be regarded as the plastic material from which all the tissues of the body are derived. It is found to be present in greater quantity in the blood contained in the veins (venous blood) than in that contained in the arteries (arterial blood). In the white of the egg and in the serum of blood it is combined or associated with soda.

One thousand parts of blood also contain about three parts of the proximate compound **FIBRIN**. But various circumstances of diet, &c., alter the quantity present. The blood of the carnivora also contains less of this compound than that of the herbivora. It may be obtained by washing the clot of blood, so as to remove the red matter which colours it, and is then found to present the appearance under the microscope of meshes of intersecting fibres. It exists, like albumen, both in solution and in a solid form. Its tendency to assume a fibrous structure on coagulating, distinguishes it from albumen. The discovery that, by the action of the juices of the stomach, and also of nitrate of potash, fibrin may be converted into albumen, is of much physiological interest.

The nitrogenized compounds of plants, albumen, gluten, and casein, possess an almost identical composition with the nitrogenized compounds of blood, and the name "pro-

* It is owing to the presence of sulphur in albumen that a silver spoon is blackened by boiled white of egg.

tein compounds," which is frequently applied to these substances, was given to them by Mulder, a Dutch chemist, who believed that he had discovered that it was possible to isolate from them a fundamental chemical compound, of which all of them, with the addition of phosphorus and sulphur, were composed. This compound he named *Protein* (Greek, *Proteuo*, I take the first place), and regarded as the starting point of albumen, fibrin, &c. This opinion of Mulder's, however, cannot be regarded as correct, as Liebig's experiments prove that this so-called protein cannot be obtained free from sulphur.

From the analysis of Lecanu, the constituents of blood may be regarded as contained in the following relative proportions in 1,000 parts :—

Water, ...	783.36
Fibrin, ...	2.83
Albumen, ...	67.25
Colouring matters, ...	126.31
Various fatty matters, ...	5.16
Salts and undefined animal matters, ...	15.09

1000.00

In the corpuscles, the inorganic matter consists chiefly of phosphates and salts of potash, while the serum contains chiefly soda salts, and chlorine compounds.

Composition of some of the Nitrogenized proximate compounds of Animals.

100 parts contain	Albumen.	Fibrin of blood.	Casein (Voelcker).	Hæmato-Crystallin (Lehmann.)	Fibrin of muscle (Syntonin).
Carbon....	53.5	52.7	53.83	55.28	55.23
Hydrogen..	7.0	6.9	7.15	7.11	7.39
Nitrogen...	15.5	15.4	15.65	17.33	15.84
Oxygen	22.0	23.5	} 23.37	20.04	20.33
Sulphur....	1.6	1.2		0.23	1.21
Phosphorus	0.4	0.3			

PART IV.

THE ORGANS OF DIGESTION.

FOR the maintenance of the life of animals, and for the preparation of the blood, the essential requisites are air, water, and food. If any of these be withheld, even for a short period, the motions of the animal machine are arrested, and death is the result. The most urgent and constant want of every animal is air, and everywhere around us nature renders it accessible; the earth yields us water in its lakes and springs, but to obtain "the daily bread" which they require, and to prepare it for their subsistence, both man and beast must labour. It is not merely the growing child and the young calf that must receive constant supplies of food. It is a condition of the life of all animals, that every motion of the body should be attended with decay. The structures of which the bodies of our cattle and our own bodies are composed are but of temporary duration, and for the continuance of life it is essential that new matter to build up bone and muscle should be regularly provided, to take the place of that which has been worn away.

Even our own bodies daily change receive,
Some part of what was theirs before they leave;
Nor are to-day what yesterday they were;
Nor the whole same to-morrow will appear.

OVID.

In the full-grown animal the materials supplied must be equal in amount to the waste matters removed. A man in a year consumes more than a ton weight of the temporary structures of the body. In urine, in the matters discharged from the bowels, in the liquids and gases which are separated by the skin and the lungs, the rubbish is carried away. In the mature fully grown animal which receives abundant food, the equilibrium between waste and repair, which constitutes health, is maintained. In the properly fed growing animal new structures are built up more rapidly than waste proceeds, while in old age this state of things is reversed.

In the case of man it is calculated that about a ton and

a half of air, water, and food are taken into his body in the course of a year, yet none of this immense mass of material is long retained, but is consumed in the processes of life, and discharged in new forms. To every animal this incessant destruction of its parts is necessary to its life. Physiology and chemistry teach us that we die, not merely every day, but every instant from the period that the first breath of air is drawn into our lungs; thus our very forms are but transitory, even while we speak they are melting away. While we write, our fingers are being changed; truly are "our figures never at a stand!" To meet, therefore, this constant wear and tear of the living machine, which of itself can create nothing, but merely acts by transforming and modifying the materials taken into it, in addition to the ever-present air and the easily accessible water, food of proper kind and in adequate quantity must be eaten, and, to prepare the substances which nature supplies for this purpose to become part of the bodies of animals, various processes are required; and as the materials which serve different animals for food must be brought into solution, and require different degrees of preparation, the machinery provided by nature to effect their conversion into a suitable condition for assimilation presents peculiarities dependent upon the habits of the animal.

The first contrivance for the preparation of the food of the Animals of the Farm is to submit it to the mechanical action of the teeth, by which it is either torn, cut, or crushed into a finely-divided state. 2. It is exposed, in its finely-divided condition, to the chemical action of liquids separated from the blood (secreted) by certain bodies called glands, six of which open into the mouth by means of small tubes or ducts. The liquid which these glands pour out into the mouth is termed *saliva*,* of which from 20 to

* Of this secretion in the horse more than two-thirds of the quantity are separated by the large gland near the ear, termed the *parotid gland*. 1000 parts of healthy human saliva contain, according to Jacobowitsch—

Water, ...	995.16
Solid constituents, ...	4.84
Epithelium, ...	1.62
Soluble organic matter, ...	1.34
Sulpho-cyanide of potassium, ...	0.06
Fixed salts—Phosphate of soda, lime, magnesia, and chlorides of sodium and potassium,	1.82

30 ounces are daily secreted by man. By its chemical action important changes are produced on the constituents of the food, its starchy matters being dissolved and converted into sugar. The further change which the food is to undergo when taken into the stomach is also promoted by the action of the oxygen contained in the large quantity of air which is churned up and retained by the pulpy matter into which the food is converted by this secretion. 3. The tongue and certain fleshy bands (muscles), connected with it, by means of which the mass of food is conveyed backwards into the gullet and swallowed.

The form and arrangement of the teeth are influenced by the habits of life of the animal, and their number differs very much in the different tribes, being adapted to the nature of the food upon which they are required to act. The solid food of our farm animals is conveyed into the mouth by the combined assistance of the teeth, lips, and tongue; water is either sucked into the mouth, or lapped up by means of the tongue. When, by the mechanical action of the cutting and grinding surface of the teeth, and the chemical influence of the saliva, the substances received into the mouth are reduced to a finely-divided pulpy condition, they are conveyed backwards into an expansion at the commencement of the gullet (œsophagus) called the pharynx. In this cavity there are openings communicating with the nostrils, and also with the internal ear. Whilst the food is being masticated by the teeth, a kind of valve called the curtain of the palate (*velum palati*), the most dependent part of which is termed the *uvula*, is applied closely to the root of the tongue. When the food has been properly masticated, and moistened by the saliva, it is pressed backwards by the tongue, and the curtain of the palate is lifted up and applied closely to the posterior part of the pharynx, so as to close the entrance into the nostrils, while, at the same time, another valve called the *epiglottis* presses over and shuts the opening of the wind-pipe, and thus the alimentary mass, pressed backwards, passes into the only opening—that of the gullet—which is left for its passage, and is conveyed into the stomach.

The expansion of the alimentary canal termed the STOMACH, into which the comminuted food is carried, is situated in the "abdominal cavity," which is separated

from "the cavity of the chest," in which the lungs and heart are placed, by means of a fibro-muscular partition—the *diaphragm*, or midriff. Behind the abdominal cavity, is the "cavity of the pelvis," in which the bladder, womb, and other important structures are contained.

All these cavities are lined by a smooth and fine membrane, which you may recognise in making an opening into the belly or chest of an animal. It is termed *the serous membrane*, and is moistened by a fluid, which is a dilute solution of albumen, which facilitates the free play of the various structures which are covered by it ; for it not only lines the walls of the various cavities of the body, but is reflected over, and closely adheres to the stomach, liver, and other organs contained in the cavities, so that it forms a shut bag, in the folds of which, yet on the outside of the bag, the various organs are enveloped. The layers of this membrane, which are reflected over the intestines, and which attach them to the backbone, are termed the *mesentery*.

When the structure of the alimentary canal is examined, it is found to consist of three separate layers, the external of which is formed of the serous membrane just described, while internally it is lined by a soft velvety membrane—the mucous membrane—which lines the entire canal, from the lips of the animal to the vent. Between these membranes, there is observed an investment of muscular fibres, some of which are disposed longitudinally, while others run in spiral and transverse directions. These fibres, by their contraction, produce the peculiar peristaltic or worm-like (vermicular) motion of the intestines, by which the food is propelled onwards in its course from the mouth.

PART V.

THE ORGANS OF DIGESTION (CONTINUED).

THE preparation of the materials which the animal receives as food, to be converted into the substance of its body, is commenced, as has been stated, in the mouth (*Fig. 5, a*) by the mechanical action of instruments termed teeth, which are firmly fixed in the jaws of the animal, and the lower jaw being moved by powerful muscular bands, the substances taken into the mouth are cut or ground into minute portions, while, at the same time, their elaboration is still further promoted by the chemical action of the saliva. The alimentary mass has yet, however, to undergo certain alterations, so as to be rendered capable of serving for the nutrition of the body. For this purpose, after being conveyed along the gullet (*Fig. 5, k*), it is collected in a receptacle termed a stomach (*Fig. 5, l*), in which important changes in its qualities are effected.

In animals that live upon food approaching in its characters to the form which it is to assume in the animal structure, the stomach consists merely of a simple expansion of the alimentary canal; such is the receptacle of the carnivora, or flesh-eating animals, which is merely a round bag. But in the ruminantia, as in the ox and sheep, we find that as the food eaten differs widely from flesh, so a more complicated machinery is necessary, and the receptacle into which it is conveyed consists of several compartments, and is divided into no less than four distinct chambers or stomachs, differing in shape and capacity, and curiously arranged so as to facilitate the perfect preparation of the nutritive matters contained in the coarse roots and half masticated herbage upon which the animals are fed. In the horse, which, though a herbivorous animal, has only a single stomach of moderate size when compared to the immense receptacles of the ox,—being capable of containing not more than about three gallons of liquid,*—the solid concentrated food which it receives undergoes a thorough mastication and exposure to the action of the salivary juices,

* The stomach of a horse which I lately examined contained exactly a gallon and a-half of liquid.

being reduced to a finely-divided condition between the flat faces of large grinding teeth moved by powerful muscles.

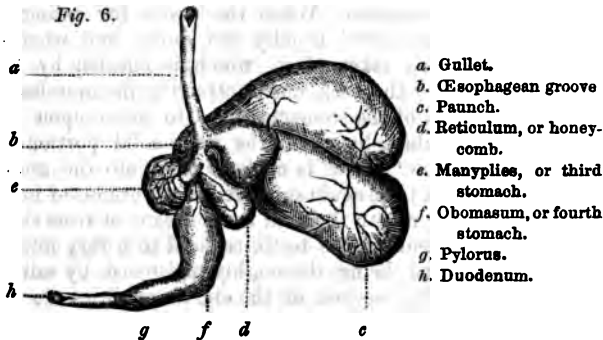
DIAGRAM SHOWING THE COURSE OF THE ALIMENTARY CANAL IN THE OX.



Fig. 5.

While in the ox, which is furnished with narrower and sharper teeth, better adapted for cutting than for grinding, a large amount of food is carried into the gullet, and conveyed to the stomach in an exceedingly coarse state. In the ox, and also in the sheep, however, there exists a curious provision for effecting the complete comminution and insalivation of their food. The half broken up alimentary matters swallowed by the animals are in the first place conveyed into one of the four compartments of which the stomach is composed. This chamber in the ox is termed the *rumen*, or *paunch* (Fig. 6, c), and is the largest of the

THE STOMACH OF THE SHEEP.



four divisions. It is placed on the left side of the abdominal cavity of the animal, and, when distended with food, occupies nearly three-fourths of the cavity. Internally this stomach is divided into two great divisions, and, by muscular bands extending across it, it is formed into a number of pouches or compartments, by means of which it is better enabled to sustain the immense mass of food sometimes placed in it. It is these bands that give this stomach the appearance termed by butchers "double tripe." In this stomach the food is stored up for some time until thoroughly moistened by its secreted juices, it then passes through a wide opening into the second stomach, the *reticulum*, *honeycomb*, or *kingshood* (Fig. 6, d), which is of a more spherical form, and of much smaller size than the paunch. It receives its name from the curious cellular

appearance which its internal surface presents, its muscular and cuticular coats being arranged so as to produce numerous ridges, which unite to form pentagonal and six-sided cells. The food contained in this chamber is usually found in a more liquid condition than in the other stomachs, as the water which is swallowed passes directly to it. On its internal surface two muscular folds form a channel or furrow, connecting the opening of the œsophagus with that of the third stomach, so that, by the momentary contraction of the muscular fibres, these openings may be made to come close together. The cells in which the camel stores up water so as to afford a reservoir for the relief of the perishing traveller in parched deserts of Arabia, are formed in this stomach. When the desire for eating is fully satisfied, the animal usually lies down, and what is termed *rumination* takes place, which is effected by the animal protruding the neck, and contracting the muscles of the abdomen and of the stomach, so as to press upon the rumen and reticulum, by which the more solid portion of their contents, the "cuds," is made to pass into the gullet and to the mouth, to be again subjected to the organs of mastication. In the mouth the food is, by means of from sixty to eighty movements of the teeth, reduced to a very finely-divided state, and, being thoroughly moistened by saliva, and mixed with the oxygen of the air, its qualities are altered, so that when it is again swallowed, the muscular folds which connect the opening of the reticulum with that of the third stomach, direct it into the third stomach, called *omasum*, and also *manyplies* or *manifold*s (Fig. 6, *e*), from the peculiar structure of its internal surface, in which numerous long plaits or folds, studded with papillæ (Lat. *papilla*, a nipple), or eminences, are found extending from one end of its cavity to the other. From this receptacle the food passes to the fourth stomach, or *obomasum* (Fig. 6, *f*), which, in its natural structure, more closely resembles the stomach in man, being smooth and of a pale red colour. It is supplied with numerous vessels which secrete an acid liquid, the *gastric juice*, which contains hydrochloric acid, lactic acid, and a peculiar organic compound rich in nitrogen, termed *pepsin*, which forms about 0·319 per cent. of the gastric juice. In the stomach of the horse only the half of its inner lining secretes gastric juice. This secre-

tion has the property not merely of converting the food into a soluble condition, but of producing chemical alterations in its characters. The organic compound, pepsin, appears to perform an important part in the changes which take place in this stomach, and, as obtained by macerating the mucous membrane of the stomach in lukewarm water, and filtering and evaporating to dryness, to be capable of exerting its effects when removed from the stomach, so as to enable us to imitate the digestive process. Thus, if we add some albuminous substance, such as the white of an egg, to water acidulated with hydrochloric acid, scarcely any solution takes place until the heat is raised to upwards of 150° , but an ounce of water, to which twelve drops of hydrochloric acid have been added, will, if we add one grain of pepsin, completely dissolve the white of an egg in two hours at a temperature of 100° . The quantity of gastric juice secreted by the dog in twenty-four hours is about a tenth part of the weight of the body, and that of a man of ordinary size from 15 lb. to 16 lb. daily. The time required for the solution of the food in the stomach depends upon its nature; usually from two to four hours are sufficient for this purpose.

The acidity of the gastric juice depends upon the presence of two acids, hydrochloric acid and lactic acid, the former of which is derived from the common salt of the food, which, when introduced into the stomach, undergoes decomposition, yielding hydrochloric acid to the gastric juice, and oxide of sodium or soda, as will be hereafter described, to the liquid secreted by the liver—the bile. Lactic acid is produced by the action of saliva on the starchy matters of the food. In the stomach, by the alternate contraction and relaxation of the fibres of its muscular coat, the food is kept in motion, and completely exposed to the solvent influence of the gastric juice, and the portions of it which have been digested are changed into a soft pulpy liquid which receives the name of *chyme*, and, when the process of chymification is completed, the chyme is forced through a valvular opening called the *pyloric orifice* (*Fig. 6, g*) into a tube called the *duodenum* (*Fig. 6, h*), which forms the commencement of the intestinal canal.

In the mouth, as we have seen, the digestive process is mainly exercised on the carbonaceous matter of the food—

the starch. In the stomach it is chiefly the albuminous or nitrogenized substances that are reduced to a soluble condition, for the purpose of supplying the waste of the muscular tissue of the animal, and of contributing to the nutrition of its body. Every hour, in the body of man, it has been estimated 62 grains of fibrin are wasted away, and this expended material is replaced by the new matters elaborated in the stomach. No sooner does the chyme pass the gate which conducts to the intestinal canal, than a new series of operations begins, and the action of the acid gastric juice is replaced by that of two alkaline liquids which are poured into the duodenum, by means of which still further changes are produced in the food, and especially in its carbonaceous constituents—its starch, its gum, and its fat. The internal surface of the duodenum presents a puckered appearance, from being formed into numberless folds termed “*valvulæ conniventes*,” by which a greater extent of surface is produced, and also a mechanical obstacle presented to the too rapid passage of the food. The intestinal canal may be regarded as a tube, commencing at the pyloric orifice of the stomach, and terminating at the orifice of the rectum or straight-gut. Its length and diameter vary considerably in different animals. In the horse its length is from 10 to 11 times that of the body, measured from the muzzle to the vent; in the ox, 22 times the length of its body; in the sheep, from 27 to 28; in the pig, from 14 to 17; in man, $5\frac{1}{2}$; in the lion, 3; and in the dog and cat, from 4 to 5 times. By anatomists it is described as divided into the small and large intestines, and these again respectively into duodenum (Lat. *duodeni*, twelve), jejunum (Lat. *jejunos*, empty, being generally found empty in the dead body), and ilium (Greek, *eileo*, I wind about,—from its twisted appearance), and colon (Greek, *koilos*, hollow), cæcum (Lat. *cæcus*, blind), and rectum (Lat. *rectus*, straight). The portion of the intestinal canal which is termed the duodenum, in man is about twelve inches in length, but in the horse it is fully twice that length; and you may form some idea of the great capacity of the intestines by the fact that in the horse the small intestines are capable of containing eleven gallons of fluid, and that although the length of the large intestines is not so great, yet, as these form the chief reservoir for the large quantity

of water which the animal drinks with its dry food, they are of sufficient capacity to contain no less than nineteen gallons of fluid.

In the duodenum the chyme is mixed with liquids secreted (separated) by two glandular bodies, *the liver* and *the pancreas*, which are conveyed to it through a tube, or, in the horse and in many other animals, by two tubes, which pour their secretions into the bowel at a short distance from each other. One of these liquids in the ox is supplied by a small bag or reservoir attached to the liver, called the *gall bladder*, but in the horse, which has no gall bladder, it is poured into the duodenum directly from the liver. This secretion is called *bile*, and is a greenish yellow-coloured alkaline liquid, of a peculiar bitter taste, and which decomposes rapidly when exposed to the air. Its chemical examination shews it to contain a resinous compound of soda, a peculiar pigment, a substance termed cholesterine, and mucus; and its ultimate analysis proves it to contain very little nitrogen, and to consist mainly of what chemists term a hydro-carbon, that is, a compound of carbon, hydrogen, oxygen—it also contains sulphur. In man about 54 ounces of it, containing 5 per cent. of solid matter, are every day poured into the intestines. During abstinence from food very little bile is secreted, the maximum flow being observed about thirteen hours after a meal, and, when not required for digestion, it is retained and stored up in the gall bladder. The constituents of the bile serve to stimulate the motions of the intestinal canal, and also serve to prevent the too rapid putrefaction of the food.

The gland which secretes the bile—the liver (*Fig. 5, p*)—is a large dense body of a reddish brown colour. In man it weighs about 5 lbs., in the cow about 16 lbs. It is placed on the right side of the abdominal cavity, between the stomach and the midriff. Its internal structure is exceedingly complicated, and, notwithstanding it has occupied the attention of many able investigators, is still imperfectly known. It may be described as composed of the capillaries, or hair-like branches of veins (the hepatic) upon which little round bodies are arranged like grapes upon a branch of the vine; these are called the lobules of the liver; of tubes or ducts called bile ducts; of the branches of an artery,—the hepatic artery,—which carries to it blood for its nutrition; and of the

branches of a large venous trunk,—the portal vein,—which is formed by the union of branches from the stomach and abdominal viscera, which subdivides into branches like an artery, and, in the glandular substance of the liver, secretes the bile, which is carried away by the bile ducts, while the residue of its blood is conveyed by the hepatic veins into a great venous tube called the *vena cava*. The liver may be regarded as co-operating with the lungs in the purification of the blood by the removal of carbon, and in the foetus, whose lungs are inactive, it is found to be of large size.

The *pancreas*, or *sweet-bread* (*Fig. 5, r*), is placed in the abdominal cavity, close to the stomach, and in its structure closely resembles the salivary glands of the mouth. It secretes an alkaline viscid liquid resembling the saliva, and which, like that secretion, possesses the property of converting starch into sugar. In man, from five to seven ounces of it are every day secreted.

By admixture with the alkaline secretions of the liver and pancreas, the acid chyme is changed into a white cream-like liquid, which receives the name of *chyle*,* which, in the passage along the intestinal canal, is mixed with certain secretions thrown out by the canal, and its nutritive matters are gradually absorbed or conveyed from the intestines to serve for the re-edification of the animal structures, while the insoluble matters of the food, which resist the action of the various solvents, are carried along the canal into the *rectum*, or last portions of the large intestines, in which they remain until they have accumulated so much as to produce an uneasy sensation, when, by the contraction of the muscles of the intestines, assisted by the pressure of the diaphragm and of the muscles of the abdomen, they are discharged as *fæces*, or *dung*. The shape of the masses of dung is produced by the folds of the intestine, the consis-

*The chyle has been found to contain the following constituents in 1000 parts :—

	In the Horse (Simon).	In the Cow (Lassaigne).
Water,.....	928.23	964.40
Fixed Constituents,.....	71.77	35.60
Fibrin,.....	0.72	0.95
Albumen,.....	49.89	28.00
Fat,.....	4.89	0.40
Extractive Matters,.....	11.42	0.55
Salts,.....		5.70

tence of the excrement depending upon the kind of animal, and its state of health, and also upon the nature of its food.

PART VI.

CIRCULATION OF THE BLOOD.

HAVING traced the alterations produced in the food in its progress through the organs of digestion, and the separation from it of a nutritive material, we shall continue our survey of the machinery by which the material thus prepared is made to become blood, and rendered capable of entering into the composition of the living structures. For this purpose, it is necessary that you should be made acquainted with the mechanism of the HEART and LUNGS.

It has already been mentioned (p. 15) that, when any part of the body of an animal is cut, blood flows from the opening. When the wound is small, it is soon closed by means of a sticky fluid which fills up the orifice, coating it over with a thin covering of size-like liquid like a water-proof varnish; this liquid, which will be presently described, is called *lymph* (Lat. *lymp̄ha*, water). But if a deep wound be inflicted, if, for example, a cut be made across the neck of an animal, so as to open the large vessels which are in that part, the blood will continue to flow until nearly all that the body contains has escaped, and the flesh will become pale and shrunken. It is therefore clear that all the canals through which that liquid is conveyed to the different parts of the body must be connected together—must communicate. Such, indeed, is the case, for though the blood may be observed to differ in colour, being in some of the tubes (the veins) which convey it, of a dark red, and in others again (the arteries) of a bright vermilion colour, yet all the blood-vessels of the body communicate. Along these vessels the blood, during life, continually flows in an unbroken stream, the motion of the current being produced by the alternate contractions and expansions of a portion of the canal which is termed the HEART. This organ may be compared to a hydraulic

machine of the most exquisite contrivance, and, like that of the engineer, is supplied with its valves, its cords, and its pipes.

In man, and the higher classes of animals, the heart is placed between the lungs in the cavity of the chest, and is supported in its place by a doubling of the pleura. It is also enveloped by a fibro-serous membrane, which encloses it as in a bag (*pericardium*, Gr. *peri*, about ; and *kardia*, the heart), and from the internal surface of which a liquid is poured out, that, like the liquid which lubricates the surfaces of the joints, serves to prevent friction.* The conical mass which the heart forms is found, when opened, to consist of four compartments, formed by the expansion of the vascular canal, strengthened by a covering of powerful muscles. Two of these chambers form the right, and two are placed on the left side of the organ, and compose what are termed, respectively, the right and left sides of the heart. The two upper compartments, from some fancied resemblance in their appearance to the ears of a dog, have, by the imaginative anatomists of early times, been termed *auricles* (Lat. *auricula*, a flap of the ear), and the two lower, *ventricles* (Lat. *venter*, belly). The chambers, or compartments of each side, communicate by means of openings closed by strong valves ; but between the two sides of the heart there is no direct connexion. It is by means of the alternate contraction and expansion of the muscular walls of these chambers, which are furnished with valves so as to operate like a double-acted force pump, that the blood is squeezed as it were into the vessels extending from them, and forced to every part of the body of the animal. In the ox and most ruminating animals, additional strength is given to the ventricles by the insertion of a bone at that portion of the chambers from which the large vessels proceed.

The movements of this wonderful engine are involuntary. It wastes away by its labours, yet repairs itself all its waste ; day and night its valves may be heard at work, and by placing your ear on the left side of the chest of a man or of a horse, you may ascertain the sounds which they produce. The physician, by the careful study of the modifications which these sounds undergo in disease, has been

* Cows occasionally swallow pins and pieces of wire, and these frequently make their way to the pericardium, and have been found sticking in it after death.

enabled to determine, with great accuracy, various morbid alterations to which the engine is exposed. Yet, though the heart performs its work without our attending to its movements, both in man and our farm animals, what are termed mental influences, as anger, fear, &c., exert an influence over them ; so that by the ancients, and even yet in popular language, it is described as the seat of the passions and the source of love and hate ; we hear every day people talking of "good-hearted" men and "bad-hearted" men.

The force with which the chambers of the heart can expel their contents, and the rapidity of the motions of the current which flows through the vessels connected with the central engine, are well calculated to excite astonishment. In man it is calculated that the force which the left ventricle exerts for the propulsion of the blood is 13 lbs. But in some of the larger animals which, like the whale, have pipes for conveying the blood several feet in diameter, the force required to drive on the stream must be enormous. In the horse, the entire mass of the blood is made to traverse the whole body in from 20 to 25 seconds, so that we can readily, from this, understand how poisons and medicines may rapidly pass into the system.

Though, as has been stated, there is no direct communication between the right and left sides of the central pump, yet the blood and the incipient blood, the chyle, poured into the reservoirs on the right side of the heart, are, after a time, conveyed to the chambers on the left side of that organ, and from them again propelled into the system of tubes in connexion with it.

The blood-vessels which proceed from the heart are of two kinds, and exhibit considerable difference in structure. Those which are connected with the left ventricle, and by which the red-coloured blood is conveyed to all parts of the system, are termed ARTERIES (Greek, *aer*, air ; and *tereo*, I keep), the ancients having supposed their use was to carry air, while the tubes which convey the dark-coloured blood to the chambers on the right side of the heart, are termed VEINS (Lat. *venio*, I proceed). The walls of the arteries are composed of three layers, the inner of which resembles the serous membrane, and is continuous with the lining membrane of the heart, the middle layer is composed of muscular fibres arranged circularly, and the

outer of an elastic tissue with the fibres arranged lengthwise. Owing to their structure, when cut across, the arterial tubes remain open, and are also capable of yielding to the intermittent current of blood forced into them by the heart, by which their length and diameter are increased; and by the contraction again of their elastic coat the stream is forced along, and the wave-like movement, communicated to it by the heart's impulse, converted into a uniform flow.

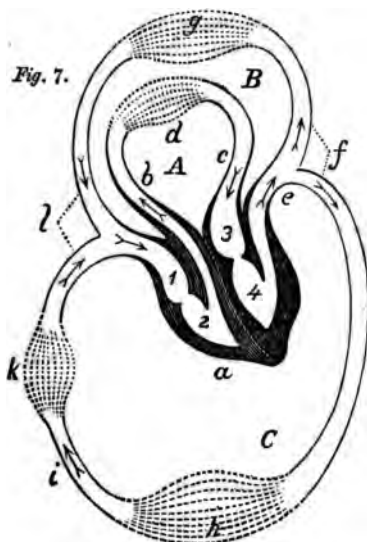
The VEINS have a much greater capacity than the arteries, so that the rapidity of the current through them is diminished. Their elastic tissue and muscular covering are not so thick as in the arteries, and their interior is furnished with flaps or valves, which open only toward the heart.

When the vessels which convey the blood from the heart are traced in their course, they are found to divide and subdivide into innumerable fine and minute branches, which penetrate into every part of the body, and finally become so small as to be no longer visible to the unaided eye. The microscope, however, enables us to discover that these terminal vessels consist of delicate membranous tubes, so arranged as to form a fine network in which hair-like (*capillary*) vessels, proceeding from the tubes (veins and arteries) connected with the right and left side of the heart, are brought closely together, and that the blood for the nourishment and repair of the system, conveyed from the central reservoir by the vessels extending from one side, is taken up and carried back to it from those in connexion with the opposite side. This curious distribution of the blood, by which it is made to pass to every tissue of the living animal, and again collected and brought back to the heart, is termed its *circulation*, and was first clearly explained by an English physician named Harvey, in the year 1619. The course of the circulation will be rendered more intelligible by reference to the diagram. You will perceive that it may be compared to the figure 8.

The blood flows from the right ventricle (2) into the pulmonary artery (*b*), which conveys it to the lungs (*A*), forming a network of capillary vessels (*d*), from which it is conveyed by the pulmonary vein (*c*) to the left auricle (*3*) of the heart, from which it is forced into the left ventricle, and by the contraction of that chamber, into the

great arterial trunk, the aorta (*e*), which divides into two main trunks (*B* and *C*), from which branches convey the nutritive stream to all parts of the body. The blood distributed by the anterior trunk (*B*) is collected by capillary vessels which unite to form a large venous trunk (*l*), which pours its contents into the right auricle, while the blood conveyed by the trunk (*C*) is collected by a vein, the portal vein (*f*), which carries it to the liver, where a system of capillary vessels (*k*) is formed, from which it is gathered up by the large vein, the inferior hollow vein, *vena cava* (*l*), and conveyed to the right auricle.

DIAGRAM OF THE CIRCULATION OF THE BLOOD.



1 and 3. The Auricles.
2 and 4. The Ventricles.

in its course,—which render it necessary that it should be brought back to the central reservoir.

It is by the alternate contraction and dilatation of the chambers of the heart, and partly by the impulse which the blood forced into the arteries communicates to these elastic coats, that what is termed *the pulse* is produced. The distending wave, which passes along the arterial conduits, can readily be perceived by pressing the finger upon one of the tubes in situations in which it can be compressed against a bone, so as to occasion a partial obstruction of the stream. As the activity, force, and regularity of the heart's action must influence the entire circulation, the examination of the

pulse, as indicative of the condition of the animal, is regarded as of great importance in the treatment of disease. It will be obvious that the most suitable situations for this purpose will be where the arteries are not too deeply seated; thus, the pastern and the root of the ear are good situations in the horse, and the pulsation of the submaxillary artery can readily be examined by pressing the finger on the spot on the lower jaw where the artery passes over the bone. In the healthy adult horse the pulse usually beats from 32 to 40 times in the minute. In farm horses the usual pulse is 36, but in the more active thorough-bred horse it is frequently 40 to 42. In the ass it is from 46 to 56; in the ox from 35 to 42; in the sheep, 68 to 80; in the dog, from 90 to 100. It must be recollected that the pulse will be increased not merely by disease, but also by every kind of excitement. Exercise, heat, and fear, also quicken the circulation, and, if not taken into account, may lead to erroneous conclusions. "When," says Youatt, "a careless, brutal fellow goes up to a horse and speaks hastily to him, and handles him roughly, he adds ten beats per minute to the pulse, and will often be misled in the opinion he may form of the animal. A judicious person will approach the patient gently, and pat and soothe him, and even then the circulation probably will be a little disturbed. He shall take the additional precaution of noting the number and quality of the pulse a second time before he leaves the animal."

PART VII.

If you trace the course which the blood follows, as it passes from the capillary vessels of the veins, to the right side of the heart, as shewn on the diagram given at page 37, you may observe that the great venous trunk in which it is conveyed, before it reaches the central organ, branches out so as to form a system of capillary vessels. This ramification of the great vein takes place in one of those *secreting organs* to which allusion has already been made — *the Liver* — and the vein has been termed the *vena portae*,

or vein of the gate, from the supposed resemblance of the portion of the Liver through which it passes to a gateway. The Liver is bound in its place close to the diaphragm, or midriff, by strong bands of *peritoneum*, and through it, in every part, the capillary branches of the portal veins are distributed, and secrete or separate from the impure blood which they carry, the peculiar liquid which is termed *the Bile*, and which is conveyed by a tube—the *hepatic duct*—to the duodenum. In the Liver, the blood is, as it were, filtered from a portion of its impurities; it is then collected again, and conveyed by the hepatic vein to the great venous trunk which flows into the right auricle of the heart. The office of the Liver is regarded as subsidiary to the respiratory process, and a mutual dependence is found to prevail between it and the lungs. By both of these organs the waste and surplus carbonaceous matters which have accumulated in the system are filtered from the blood.

The Bile is usually a greenish yellow, oily, and somewhat viscid liquid, of an intensely bitter taste. It froths up like a solution of soap in water when briskly agitated. Late researches (Strecker) have shewn that it is a mixture of two salts, compounds of acids containing nitrogen, named cholic and choleic acid, and the alkali soda. Choleic acid also contains sulphur. Sheep bile, and that of fish and serpents, contains about 6 per cent. of sulphur. In addition to these ingredients, bile also contains a peculiar colouring matter, and fat. It is remarkable, that while the bile of the ox, and other herbivora, contains almost exclusively soda salts, that of salt-water fishes contains chiefly potash salts. The ash of the bile also affords to analysis the usual saline matters which occur in animal liquid, common salt, which forms 28 per cent. of the ash of the ox bile, being the predominant constituent.*

Bile, then, like blood, is a mixture of several bodies coloured by a pigment which, however, is held in solution

* Composition of Bile (Frerichs) 100 parts contain :—

Water, ...	85.96
Solid Substances,.....	14.04
Cholate and Choleate of Soda,.....	8.18
Cholesterine	0.21
Fat,.....	0.62
Mucus,.....	2.82
Salts, ...	0.71

and not merely suspended like the colouring matter of the blood. The bile pigment may be dissolved out from it by the action of alcohol; and by passing the solution, which has the colour of the Bile, through a layer of charcoal powder, it will be retained, and a colourless solution will pass through the filter containing all the other constituents of the mixture. Ether also dissolves from bile, fat precisely resembling the fat of the other parts of the animal body, and it is found to contain mucus of the same kind as that which lubricates the lining membrane of the intestinal canal. These substances, therefore (*Liebig, Familiar Letters*, p. 255), are not essential to the bile, and its characters are regarded as depending upon the presence of the peculiar bitter compound. According to late researches (Bernard) the liver has the power of secreting a substance closely resembling starch in composition, which, when it comes into contact with the blood of the hepatic vein, is transformed into sugar (glucose), which is in its turn decomposed in the capillaries of the general circulation.

The secretion of the bile in the liver is continuous, but we possess no estimate of the amount produced in any given period which can be relied upon as exact. In man the quantity secreted has been found to be greatest about twelve hours after food had been eaten. Fat animals yield less bile than lean ones, as the disposition to accumulate fat is usually accompanied with a diminished activity of the respiratory process, and a consequent slow decomposition of the tissues. When the passage of the bile into the bowels is obstructed, it enters into the blood, producing the disease termed *jaundice*.

In the experiments on dogs, it was found when no bile was allowed to flow into the intestinal canal, and when, at the same time, the animals were fed on flesh, that a condition analogous to flatulent dyspepsia was induced; the food was rapidly decomposed, evolving foetid gases, the fæces smelled like carrion, and there was a continuous rumbling of the abdomen. When bread was substituted for flesh, the fæces discharged were sour rather than putrid, the gases evolved were odourless, and the abdominal uneasiness ceased. When openings were made in dogs, so as to produce a discharge of bile, it was found that they rapidly lost weight, *though supplied with abundant food, of which they eat*

voraciously, and that they all suffered from putrefaction of the contents of the bowels. The experiments of Drs. Bidder and Schmidt shew that not more than one-eighth, and probably less than one-fifteenth part of the solid matter of the bile is exuded from the body, but that it is chiefly re-absorbed from the contents of the intestines before they arrive at the anus. The offices performed by the bile, so far as the present knowledge extends, may be regarded to be—1st. To facilitate, in some manner not yet clearly determined, the absorption of oleaginous matters. 2nd. To prevent the putrefaction and too rapid decomposition of albuminous food, so as to allow of its being as long as possible, without injury, exposed to the absorbing surface of the intestines. 3rd. To separate substances imperfectly fitted for assimilation, and again to take them up and convey them into the current of the circulation.

In the ox, as has been stated, the biliary secretion is collected in a reservoir called the gall-bladder, which communicates by a tube or duct with the duodenum. This reservoir, however, is not present in all the mammalia: thus, it is absent in the horse, camel, and deer, but exists, as stated, in the ox, and is also found in the sheep and pig.

The various saline and gaseous matters required for the nourishment of plants, you are aware, are sucked up from the soil dissolved in water by innumerable rootlets. In the animal, distributed over the membrane which lines the alimentary canal, and in contact with the liquefied food, we recognize somewhat analogous organs, termed *lacteals*, from the milk-like fluid which they contain. The office of the lacteals is to absorb the chyle into which the contents of the stomach have been converted. The internal lining of the small intestines, when examined, is found to be studded with shaggy projections, termed *villi*, from the velvety appearance which they cause it to assume. In these villi the rootlets or terminal branches of the lacteals are distributed. The microscopic investigations which have been made of the structure of the villi are exceedingly interesting. Thus each villus has been shown to contain the commencement of a lacteal tube, which does not, however, exhibit any aperture, but is inclosed in areolar tissue, and protected by

a covering composed of a scaly membrane, termed epithelium, analogous to the cuticle of the skin. Below the epithelial covering are discovered very minute cells, into which the chyle passes into the lacteal vessels by osmotic action, that is, in accordance with the law of exosmose and endosmose, already explained. The lacteal tubes convey the matters which they have absorbed into a reservoir, which, however, not only receives their contents, but also serves as a receptacle for a portion of the used up, worn out tissues of the body, conveyed to it by another set of absorbent vessels termed lymphatics, which are distributed to every part of the body. A portion of the waste matters, you have heard, is removed or excreted, but another portion is selected to be worked over again, and converted into new forms. The old building materials are not all destroyed by being once employed, but some useful matters may be picked out of the rubbish, and this selection is performed by the lymphatics.

Both lacteals and lymphatics, before pouring their contents into the common reservoirs, are made to pass through knot-like bodies, termed *glands*, formed by the vessels which become twisted into numerous convolutions. In these bodies the absorbed liquids are delayed in their course, and important changes, the exact nature of which are still but imperfectly known, is produced in their characters. Thus, the examination of the liquid contents of the lacteal tubes shows, that as it approaches the reservoir its composition more nearly assimilates to that of the blood. At the commencement of its course it does not possess the power of coagulating, but when it has reached the reservoir it is found to coagulate readily, and thus elaborated, it is conveyed in the higher animals by a tube which passes from the receptacle and is poured into the current of the circulation, where it becomes more highly organized and assumes all the characters of red blood. Thus, the circulating liquid is made up, not only of the new nutritious materials derived from the food, but of matters absorbed from the wasting tissues of the body, lymph, &c. In many of the lower animals, the polyps, some worms, and mollusca, the liquid absorbed from the digestive tube by the lacteals undergoes no further change, but in all the vertebrata, *before it can form liquid flesh suitable for being moulded*

into the tissues of the body, it must be more highly elaborated.

The vessels conveying the lymph are not, like the blood-vessels, connected with a central suction pump, but they are furnished with valves which open only in the direction of the current that is towards the heart ; and when, by the various motions of the body, the tubes are subjected to pressure, and their sides pressed together, some of their contents are forced outwards, and when the pressure is withdrawn and the tubes again expand, a new portion of liquid takes the place of that expelled. The rapidity, therefore, of the transmission of liquids along the tubes will materially depend upon the activity of the whole system of the animal. The absorbent glands connected with the lymphatics are very numerous in the sides of the neck, and on the inside of the arms and thigh. They are supplied with a great many blood-vessels, and when deleterious matters, as in dissection, wounds in man, or phary and other affections in the horse, pass into them, they inflame and enlarge, producing hard and painful tumours, as is observed in various diseases of farm animals. The disease termed *glanders*, receives its name from the swelling and inflammation of the glands under the jaw, by which it is accompanied.

In an examination made by the French chemist, Chevreul, of lymph taken from the thoracic duct of a horse after five days' abstinence from food, it was found in 1000 parts to consist of—

Water, ...	926·4
Fibrin, ...	4·2
Albumen, ...	61·0
Chloride of Sodium, ...	6·1
Carbonate of Soda, ...	1·8
Phosphate of Lime, ...	} 0·5
Carbonate of Magnesia, ...	
Carbonate of Lime, ...	
	1000·0

Both in its physical and chemical characters, the lymph approaches closely to the serum of the blood. Its saline constituents are the same, and have the same composition

as those of blood ; thus analysis shows them to possess the following composition :—

	Salts of the Serum of the horse.	Do. of Lymph.
Alkaline Chlorides, ...	4·055	4·123
Alkaline Carbonates, ...	1·130	1·135
Alkaline Sulphates, ...	0·311	0·233
Alkaline Phosphates, ...	0·115	0·120
	5·611	5·611

PART VIII.

HOW THE BLOOD IS PURIFIED.

“ He breathed into his nostrils the breath of life, and man became a living soul.”

FROM birth to death the animal requires that air should be conveyed into its system. Air is, indeed, to every animal “ the breath of life.” Our first efforts are made to obtain it, and our last breath is drawn when our power to renew the supply no longer continues. There must, therefore, be something in this air, some vital principle, which renders it so indispensable. By chemical analysis, this air that we breathe is found to consist, in every 100 parts, of about 23 parts of oxygen gas and 77 parts of nitrogen. By measure, as oxygen weighs somewhat more than the nitrogen, the proportions are, in 100 measures, gallons we may say, 21 gallons of oxygen, mixed with 79 gallons of nitrogen ; and in addition to these gases, we find in every 2,500 gallons of air about one gallon of carbonic acid. Such, then, are the main ingredients of that invisible aerial ocean which, to a depth of forty-five miles, surrounds our globe, and in all animals, even in the lowest forms of existence, we find arrangements, variously modified, in accordance with the medium in which the animals live, by which it may be conveyed into the interior of their bodies. In the mammalia, in birds, and in reptiles, which are said “ to live in air,” the organs for this purpose are contained in a large *cavity called the thorax*, or cavity of the chest. The upper

part of which is formed by the spine, or vertebral column, the lower part by the *sternum*, or breast bone, the sides by the arched plates of bone termed *ribs*, which, like the ribs

GENERAL VIEW, SHEWING THE POSITION OF THE ORGANS OF RESPIRATION IN THE HORSE.



of a boat, extend downwards from the vertebræ, or pieces of which the spine is composed. The ribs are attached to the spine by moveable joints, and are connected together by muscles, called *intercostals*. The pos-

terior part of the cavity is closed by a strong muscular and tendinous web, the *diaphragm*, or midriff, which separates the organs contained in it from those enclosed in the cavity of the abdomen. The shape of the thorax in the Animals of the Farm differs very much from that of man (see *Fig. 8*), and is narrowed and shaped somewhat like the keel of a boat; in the horse, this keel-like shape is more remarkable than in the ox, and is admirably adapted to facilitate the easy flexion and extension of the fore legs of the animal. The diaphragm exhibits an interesting arrangement of structure which deserves our consideration; thus, we observe that its central part is pierced by two holes, through one of which the gullet passes on its course to the stomach, while the other affords a passage to a large vein connected with the liver. If the entire partition had been formed of muscular fibres, both the vein and gullet would be compressed and obstructed by their contraction, but this is obviated by the central portion, through which these pass, being tendinous.

The organs of respiration contained in the cavity of the chest communicate with the atmosphere by means of a peculiarly shaped apparatus, called the *larynx*, which is a box formed of a number of pieces of cartilage or gristle, placed at the back of the mouth, which is made to serve both as the conduit for the air to the lungs and as the organ of voice (*Fig. 8, c*). One of the pieces of gristle or cartilage which compose the larynx is termed the *epiglottis*. It is a little heart-shaped flap or valve, which, when food is being swallowed, closes down like the lid of a box, so as to prevent any foreign substance entering into the air passage; at all other times the lid is open, so that the air can freely pass into the chest.

The mucous membrane which lines the larynx is exceedingly sensitive, and we all know from experience that if even the most minute particle of food has, as it is said, "gone the wrong way," it immediately detects the presence of the intruder, and does not rest until its convulsive efforts succeed in expelling it. In the ox and sheep, as in man, the air is drawn in both by the mouth and nostrils; but in the horse the nostrils alone are employed for this purpose, and the nasal passages are much larger than in other animals. There is also in the horse a peculiarly-shaped

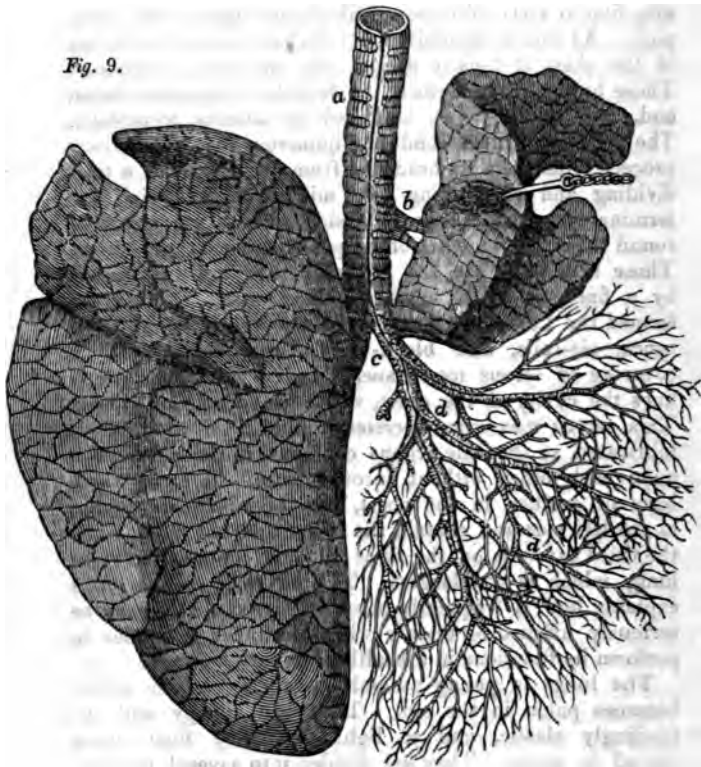
cavity, or *cul de sac*, called the false nostrils. Connected with the larynx is a tube, also composed of pieces of gristle, arranged so as to form a series of circular elastic rings, which are connected together by elastic tissue, and lined internally by mucous membrane, forming a pipe which is termed the windpipe, or *trachea*. In the ox, there are from fifty-five to sixty of these cartilaginous rings in the windpipe. As this air conduit passes backwards into the cavity of the chest it usually divides into two main branches.* These branches are termed the *bronchi*, or *bronchial tubes*, and, like the windpipe, are lined by mucous membrane. The bronchial tubes send out numerous branches, which proceed from them as branches from the trunk of a tree, dividing and subdividing into minute twigs, which are terminated by little bags or vesicles, which are clustered round them like bunches of grapes hanging on the twigs. These little bags are the *air-cells*; they are surrounded by a fine network of capillary blood-vessels. What are termed the LUNGS are made up of the aggregate of these tubes, air-cells, and blood-vessels, surrounded with a covering of serous membrane, reflected from that which lines the cavity of the chest, which is called the *pleura*. This serous membrane secretes a fluid with which it is lubricated, so that the organs contained in the chest move upon each other without inconvenience. It forms three bags or cavities in the chest, two of which are placed in the left side and contain the heart and left lung, while the third cavity is on the right side and contains the right lung, which is the largest. This division of the lungs explains how it frequently happens that one lung may be seriously affected by disease while the other continues to perform its functions in a healthy manner.

The lungs in young animals have a red colour, which becomes paler in the old. They are spongy and exceedingly elastic, and so light that they float when placed in water. They are divided into several portions or masses, termed lobules, connected together by areolar tissue, which constitutes what is described as the *interlobular tissue*, and is largely developed in the ox. In the living animal, the lungs, when fully expanded with air,

* In the ox and sheep an additional branch is sent to the right lung. (See Fig. 9.)

and the heart and the blood-vessels connected with them, completely fill the cavity of the chest. The taking in of air, or *inspiration*, is effected mainly by the large partition which separates the chest from the abdomen being drawn

THE ORGANS OF RESPIRATION OF THE OX.



a. Trachea, or windpipe.

b. The third bronchial tube of the ox.

c. The two main bronchial tubes.

d. Ramifications of the bronchial tubes.

backwards, or downwards, as in man, by which the cavity of the chest is enlarged and the elastic air-cells opened, so that the air rushes into them through the trachea.

Inspiration is also promoted by the action of the muscles which pass between the ribs. The expulsion of the air again, or its expiration, is also, in great part, owing to the movement of the muscular partition, or midriff, which presses against the elastic lungs, aided by the contraction of the muscles of the abdomen. A good idea of the position, in the horse, occupied by the diaphragm, which forms the posterior boundary of the cavity of the chest, may be obtained by drawing a line from the region of the kidneys, immediately behind the saddle-seat, and terminating at a short distance behind the girths, at the breast bone (Dr. Carson).

Having described the mechanism by which the air is drawn into the bodies of the higher animals, let us now consider whether it undergoes any alteration in its composition during its temporary sojourn in the cavity of the chest. Some simple preliminary experiments will enable you more clearly to understand what we have to communicate on this matter. First—Place a dry glass for a few seconds before the jet of steam issuing from the spout of a tea-kettle, and you will find that the surface of the glass becomes covered with a film of moisture, proving that the vapour contains water. Second—Take a bottle, and having introduced into it some pieces of limestone, pour upon the bits of gravel some spirits of salts, diluted with about twice its bulk of water, and close the bottle with a cork, through which a bent glass or tin tube is passed and made to dip into a glass containing some *clear* lime water, you will observe that as the bubbles of the gas given off, which is, you are aware, carbonic acid, come into contact with the lime water, it becomes milky looking, from the formation of a solid opaque compound of the gas with the lime, so that lime water is used as a *test* of the presence of carbonic acid, as it invariably forms with it this white compound, *carbonate of lime*. Now, if you take a new tobacco pipe and blow air from your lungs through it into a dry ale glass, you will see that very soon the interior of the glass will lose its transparency, and become coated over with moisture, so that the air we throw out from our lungs *contains water in the state of vapour*. Second—If you place some clear lime water in a glass, and blow air from the lungs through it

with the tobacco pipe, you will find that precisely the same change will occur as when the gas from the limestone was passed into it: it will become milky and opaque, proving that *it contains carbonic acid*. If you were to draw the air from the atmosphere through the lime water it would scarcely alter the appearance of the solution. Air contains, you may recollect, only one gallon of carbonic acid in every 2,500 gallons. It would therefore be necessary to draw a large quantity of air through the lime water before enough of the compound would be formed to give it a milky appearance; but by blowing the air from the lungs into it, its appearance is rapidly changed. The quantity of carbonic acid in the air must, therefore, have been increased very much by being taken into the lungs; and by exact experiments and repeated investigations this has been found to be the case. When we draw air into our lungs it contains, as already stated, only one gallon of carbonic acid in every 2,500 gallons; but when we throw it out again in expiration, after it has entered into the air-cells, it is found to contain more than the same amount of carbonic acid in every 100 gallons. The changes, therefore, which the air undergoes by being respired are—1st, the increase of its moisture; 2nd, the addition to it of an increased quantity of carbonic acid; and 3rd, a consequent diminution of the quantity of oxygen which it contained.

The air which escapes from the lungs of animals has been compared to the smoke which is given out from the chimney of a furnace in which wood is consumed. In the combustion of wood we have carbonic acid and water, produced by the union of the oxygen of the air with carbon, and of oxygen with hydrogen; and, as the burning continues, the whole of the carbon and hydrogen of the wood volatilize and disappear. The source both of the carbon and hydrogen thrown off in the respiration of animals must, it is clear, be the constituents of their bodies; and, accordingly, when animals are unable to swallow, or are from any cause deprived of supplies of food to make new blood to replace the matters consumed, emaciation rapidly ensues. Life, we have seen, in the animal, exhibits a constant succession of processes for the *destruction and renewal of its parts*; that which is built up to-

day is removed to-morrow, to be replaced by new material. The waste portions and broken up building materials of the structures, we have seen, are poured into the current of the circulating blood, which has been compared to a river which, flowing through a populous city, serves not merely to supply the wants of its inhabitants, but conveys from them all the impurities which from various channels find their way into its stream. The nutritive stream, the pure arterial blood, in its course becomes so much loaded with carbonaceous and other impurities as to be no longer capable of performing its offices, and in its course assumes the dark hue of the blood contained in the veins. The newly-formed nutritive material must also be purified before it can take its part in the work of repair. This purification and re-conversion of the venous into arterial blood it is the office of the lungs to accomplish. The active agent in this work is the OXYGEN gas of the inspired air. It is truly, as it was at one time termed, the "vital air," without which the processes of life could not be maintained, and the provisions which are made for the complete exposure of the blood to its action are of the most wonderful and interesting character. Thus we have the lungs made up of air-cells, communicating with the atmosphere by the windpipe, and giving us a surface for the action of the air, which, in man, is calculated to present an area of about one hundred and sixty square yards. Over this extensive surface we have spread a close network of hair-like blood-vessels, so that the air which conveys oxygen to the blood is merely separated from it by an extremely thin moist membrane. The great central organ of the circulation, the heart, with every stroke impels into the pulmonary arteries,—the branches of which ramify on the walls of the air-cells,—a quantity of blood which, in man, is estimated to be about five or six ounces, and every minute it forces through the lungs and exposes to the air from twenty-two to twenty-seven pounds. By respiration, also, the renewal of the air in the chest is regularly effected.

The rapidity with which respiration takes place varies with various conditions of the animal, as age, rest, motion, health, and food. A healthy adult man at rest respire, on an average, seventeen times in a minute, and

takes into his chest about 20 or 25 cubic inches of air at each inspiration; the ox respires from twelve to twenty, the horse from eight to twelve, the sheep from fifteen to twenty times in the minute, and at each expiration a portion of the used air is expelled and replaced by fresh air. The average quantity of air which the chest in man can contain, as estimated by the spirometer (Lat. *spiro*, I breathe; and *metior*, I measure), is 225 cubic inches.

It is essential to health that fresh, unused air, containing a proper amount of oxygen, should be introduced into the body of the animal. If animals are confined in close apartments, and obliged to breathe over and over again the same air, it becomes, in a short time, unfit for its purposes; the venous blood cannot be purified, and, unless fresh air be admitted, the poisonous carbonic acid gas which is given out exerts its deadly effects, and death ensues. To keep cattle in health, or our own bodies in a sound condition, it is, therefore, obvious that an unlimited supply of pure air is an essential requisite.

The essential change, therefore, which the air drawn into the lungs experiences is the removal of a portion of its oxygen gas, and the substitution of a quantity of carbonic acid. The activity both of the muscular and nervous systems of animals depends upon the action of oxygen upon their materials. This gas is the chief supporter both of life and heat. Without its presence no fire could burn—no animal could live. Air, therefore, must be introduced into the animal body, and by the combustion or slow oxidation of the constituents of the tissues, or the combustible articles of the food, such as sugar and fat, as in other cases of combustion, heat is given out to maintain that temperature essential to health; and as the accumulation in the system of carbonic acid would be injurious, by the organs of respiration the animal is enabled to effect its removal, and also obtain the supplies of oxygen requisite for the continuance of its functions. All the products of the oxidating action of this gas, which can assume the state of vapour or gas, are removed by the lungs, while such as cannot be converted into these conditions are discharged by other organs.

The venous blood which is conveyed to the lungs from *the right side of the heart*, by the so-called pulmonary

arteries, on being exposed to the action of the inspired air, is made to assume the bright red colour of arterial blood. The inspired air does not come into direct contact with the blood circulating in the capillaries of the lungs. This is prevented by the walls of the blood-vessels and of the air-cells, nevertheless an interchange of elements is effected, and the carbonic acid, which has been produced by the action of the oxygen gas, conveyed to every part of the body by the circulating fluid, and which has been carried to the lungs, is removed, and a fresh supply of oxygen is obtained. Before the interesting discovery of the permeability of animal tissues to liquids and gases (see Part II.) had been made, no satisfactory explanation of the mode in which this interchange of elements is effected could be given. We have now, however, good reason for believing that it takes place in accordance with those curious physical laws of diffusion, which have been so ably investigated by the Master of the Mint, and others. The venous blood sent into the lungs loaded with carbonic acid, derived from the decomposition—that is, the oxidation—of the tissues of the body, is separated from the air taken into the air-cells merely by a delicate partition of moist membrane. The carbonic acid and the watery vapour, or condensed steam, and a portion of nitrogen pass from the blood through the walls of the pulmonary capillaries and air-cells, and in exchange, the pure air which has been received into the cells of the lungs passes into the blood. If we were to tie up some venous blood in a bladder, and place it in a vessel containing oxygen gas, precisely the same changes would be produced as in the blood which circulates in the vessels of the lungs—a portion of carbonic acid would be found to escape, and a portion of oxygen to have entered into the liquid in the bladder, which would assume the florid hue of arterial blood. You must frequently have observed that the colour of blood drawn from the veins of an animal rapidly changes—simply by exposure to the air, it assumes the red hue of arterial blood. The essential change, therefore, which is produced by respiration on the blood, consists in the absorption of oxygen and the liberation of carbonic acid. When we draw the air into our lungs in inspiration, it contains only

two gallons of carbonic acid in every 5,000 gallons; but when we throw it out again in expiration, it is found to contain more than the same amount in every 100 gallons.* Every living animal, therefore, is continually throwing out into the air a large amount of charcoal, the product of the waste matters of its tissues. It has been estimated that a full-grown man gives out in this way about eight ounces of carbon in the twenty-four hours, and a cow about five times as much. The respiratory process, it is obvious, must powerfully influence the whole economy of the animal. It has not inaptly been designated by Liebig, in one of his classical works, as "the falling weight—the bent spring—which keeps the clock in motion; the inspirations and expirations are the strokes of the pendulum which regulate it." It will be necessary again to return to the consideration of the effects produced by the absorption of oxygen, and the separation of carbon from the animal body, but this part of our subject will be explained with greater advantage in connexion with our proposed survey of the laws which regulate the nutrition of the animal, and the practical rules which may be deduced from them for the guidance of the farmer.

We have traced the blood in its course from the heart to the capillaries of the arteries distributed through the various structures of the body, and from these along the veins to the right auricle, by which it is forced on a second circuit to the lungs, where, purified as described, by the influence of the atmospheric oxygen, it is taken up by another set of capillary vessels, branches from which unite to form what are termed, though containing blood which has become arterial in its character, the *pulmonary veins*, by which it is conducted to the upper chamber of the left side of the heart—the *left auricle*. By the contraction of the walls of this chamber it is forced into the *left ventricle*, which again propels it (its return into the auricle being prevented by the *valves*) into the great arterial trunk, the aorta, and thus sends it once more on its course to all the tissues of the body.

* The quantity of carbonic acid in the expired air is subject to considerable variation, depending upon age, temperature, atmospheric pressure, diet, &c. Its usual amount is from 3·3 to 6·2 per cent. The quantity of water in the expired air amounts to about 1 lb. in 24 hours.

PART IX.

THE SOLID FRAMEWORK OF THE ANIMAL.

ON making an examination of the body of a dead horse or cow, we find that, externally, the whole animal is covered with a coat of firm skin, and, on removing this coat, we discover below it flesh arranged in thin plates, or thick bundles, of various forms—the *muscles*—bound to a solid framework, composed of numerous pieces, connected together by joints. This framework, which is termed the *skeleton*, gives the animal its peculiar shape, and protects its organs from injury. The pieces of which it is composed constitute, in man and the animals of the farm, the passive instruments of motion, and serve as levers upon which the muscles act. In its general form, the skeleton is different in the different animals, but a close examination enables the anatomist to trace a striking resemblance in the several parts of which it consists in all the higher animals. In vertebrated animals, it is mainly composed of the peculiar substance termed *bone*, which consists of an organic compound characterised by forming a solution with hot water, from which it gelatinizes on cooling, hardened by a deposit of earthy matter, of which phosphate of lime is the chief ingredient. It consists of a great number of pieces (in man of 249), connected together by bands, termed *ligaments*, formed of fibrous tissue. The arrangements which the skeleton presents for facilitating motion and preventing injury, both in the shape of the various parts and in the mode in which they are joined together, are exceedingly interesting. Where but a limited degree of motion is required, the bond of union between the bones is generally a disc of elastic material (*cartilage*), placed like a cushion between the opposite surfaces. In other situations, where freedom of motion is necessary, the pieces are not so closely bound together, and their surfaces are covered by a smooth layer of cartilage, and lined by a delicate membrane, which secretes a yellowish-white glairy fluid, termed the *synovial liquid*, by which the joints are lubri-



Fig. 10.

- A. Occipital bone.
- B. Parietal bone.
- C. Horn.
- D. Eye.
- E. Nose.
- F. Lip.
- G. Face.
- H. Cheek.
- I. Dewlap.
- J. Brisket.
- K. Chest.
- L. Neck.
- M. Shoulder blade (Scapula).
- N. Shoulder points.
- O. Crops.
- P. Back.
- Q. Loins.
- R. Hips, or Huels.
- S. Thurl, or Whirl-bone.
- T. Rump.
- U. Plates of the Belly.
- V. Flank.
- W. Cord of the Tail.
- X. Forearm.
- Y. Thigh.
- Z. Hook.
- a. Elbow.
- b. Leg or Shank, or Cannon bone.
- c. Ear.

cated, so that they can readily be moved with the least possible friction. Externally, the bones are dense and firm, and covered over with a membrane termed *periosteum*, but internally, porous, and frequently spongy in their structure. They are generally perforated with numerous canals, through which vessels convey the blood required for their nutrition. In the skeleton of young animals, the amount of the solidifying earthy matter is but small, and the bones are soft and yielding. But, as the animal increases in size, the walls of the cells of which their substance is formed become condensed, and so much phosphate of lime is deposited in them as almost to obliterate the cavity of the cells. The deposit of phosphate of lime, and the consequent hardening of the bones, is hastened by whatever causes an increased supply of the blood which is conveyed to them; thus, in animals exposed to severe labour, we find that the bones consolidate rapidly, and when young animals are made to use violent exertions, the skeleton becomes soon firm; but as the too early solidification of the bones prevents its proper development, the growth of the animal is stunted. From undue exertion, also, we occasionally find horses with joints rendered stiff by the deposit of phosphate of lime, and exhibiting bony tumours, termed *splints* and *spavins*. In the Agricultural Museum in Queen's College, Belfast, there is a specimen of the backbone of a horse in which all the separate pieces are consolidated into a single unyielding bone. It belonged to an old cart horse. When a horse has got "a stiff back" of this kind, if he lies down he is unable to regain his feet. In the early stages of animal life, the substance termed *cartilage*, or gristle, occupies the same place as the solid bones, which, in full-grown animals, form the frame of the body. In the mature animal, we find it composing all those parts where a greater degree of elasticity is required than the bones possess; thus we discover it, as already stated, in some places connecting the bones together, and joined into long stripes, it binds the ribs to the breastbone; it is also used in the construction of the windpipe. Cartilage consists chiefly of a peculiar kind of gelatine, which differs somewhat in its characters from that which enters into the composition of bones. The following analyses will

serve to shew the proportions in which the organic and earthy matters are found to exist in the bones of animals when completely deprived of water :—

COMPOSITION OF THE BONES OF MAN AND OF THE COW.

	Man.	Cow.
Organic combustible materials, ...	33.30	33.00
Phosphate of lime, ...	51.40	55.45
Phosphate of Magnesia, ...	1.16	2.05
Soda and common salt, ...	1.20	2.45
* Carbonate of lime, ...	10.30	3.85
Fluoride of calcium, ...	2.00	2.90
	99.36	99.70

From these analyses you will perceive that the solid framework of the animal consists chiefly of a compound of phosphoric acid, and of the earthy matter (lime) which we discover in the rocks of our mountains. These substances are absolutely necessary to give solidity to the bone, and no substance which does not contain them is capable by itself of maintaining the body in health. Some time ago, in the hospital for foundlings in Paris, a diseased state of the bones was found to prevail among the poor children. They had become weak, and their limbs were unable to support the weight of their bodies; and, on inquiry, the discovery was made, that owing to an increase in the price of milk, the attendants had substituted arrow-root, which contains no phosphate of lime. An interesting illustration of the two-fold nature of the substance of which the bones of animals are composed, is afforded by placing a piece of bone in some muriatic acid (spirit of salts) diluted with water. In the course of two or three days, all the earthy matters of the bone will have dissolved in the acid, and of the firm and hard bone merely a soft jelly-like copy will remain, composed of the gelatine or organic matter of the bone. Again, if we burn a piece of bone in the fire, the glue-forming organic matter will be decomposed into invisible gaseous compounds, and a brittle mass of earthy matter will be left behind.

The separate pieces of bone which make up the skeleton

* The researches of Von Bibra and Fremy shew that the amount of carbonate of lime is larger in the bones of herbivorous than in those of *carnivorous animals*.

may be divided, as will be obvious by an inspection of the drawing (*Fig. 10*), into two divisions. Thus we have—1st, a series of bones, forming an unbroken chain, extending from the head to the point of the tail; and 2nd, a number of bones attached to these forming the limbs or passive instruments of locomotion. The pieces which compose this chain are technically termed *vertebræ*, from the Latin word *verto*, I turn; and the entire chain, *the vertebral column*. Each separate piece of the column consists of a body, and certain projecting ridges of bone which extend from it, termed processes. In the horse, the processes, which extend upwards, forming a row of spines, are very prominent, and receive the name of *withers*. They serve to give attachment to muscles, and especially to a powerful ligament or band which suspends the weighty head of the animal in its position. In man, the skull is poised on the end of the erect vertebral column; but in the horse, ox, and other animals in which the column is horizontal, a strong elastic band extends from the back of the skull to the withers. This band or ligament is sometimes called the *pax wax*, and is composed of an exceedingly elastic tissue. In the Museum of the Royal College of Surgeons in London there is a specimen of it taken from the giraffe, which is stated to have been upwards of eight pounds in weight, and six feet two inches in length. On separating it from its attachments it contracted to four feet.

The body of each vertebra consists of a short cylindrical piece of bone, from which the processes extend upwards, forming a small bony arch, and below, so as to produce a larger arch. The superior arch joined to the other vertebrae placed beside it form a canal, termed the *spinal canal*, which extends from the neck to the loins, and serves to contain an important part of the nervous system, *the spinal chord*, or marrow. From certain peculiarities in their form, the vertebrae are divided into those of the neck (*cervical*), back (*dorsal*), and loins (*lumbar*). The vertebrae of the neck, or rack bones, are always seven in number in the mammalia, but exhibit a different outline; thus, they are straight in the ox, but bend to one side in the sheep, giving that animal its wry neck. The dorsal vertebrae form the *chine*, or back, and differ in number in different animals. In man they consist of twelve separate

bones; in the horse of eighteen; in the elephant of twenty; and in the ox and sheep, of thirteen. The lumbar vertebræ consist of five bones in man, in the sheep, and in the ox; in the horse, of six; in the lion, of seven; and in the whale, of nine, which is the largest number found in any of the mammalia. Below the bones of the loin the vertebræ spread so as to form a flat bone (*sacrum*), which in young animals consists of several pieces, but in adults is consolidated into a single strong bone. The sacrum is connected on both sides with the hip bones, and, like the other vertebræ, forms a canal for the spinal cord, which, however, does not extend beyond it, but merely sends off some nerves to the tail, which consists of a number of short bones, connected together by elastic cartilage. In every part of the canal in which the spinal cord is contained, it is completely enclosed by a covering of bone, except at a point in the neck, between the first and second of the cervical vertebræ. It is this opening that is selected by butchers to kill animals instantaneously, and without the effusion of blood, by *pithing*, as it is termed, which is effected by plunging a sharp-pointed knife into what they term the "pith" of the neck.

From the vertebræ of the back, an under arch of strong flat bones extends like the ribs of a boat; these are termed *the ribs*. Their number, on each side, corresponds to the number of the dorsal vertebræ; thus, they are twelve in each side in man, eighteen in the horse, and thirteen in the ox and sheep. They enclose the chest in an almost circular form, and when too much flattened in the horse, the animal is termed flat-bellied; a characteristic mark of the improved breed of oxen and sheep, is a perfectly arched form of the ribs. The ribs consist of two kinds, that is, of ribs which are connected in the front with a narrow flat bone called the *sternum*, or breastbone, and which are named *true ribs*, and ribs termed *false ribs*, which, like those just mentioned, are connected directly with the vertebræ, but in front are merely joined to the other ribs by an intervening cartilage. By this mode of union, greater freedom of motion is allowed to the walls of the chest. In the horse, there are seven true and eleven false ribs; in the ox and in the sheep, eight true and five false.

Connected with the cervical vertebræ, in front, is the *skull*, or *cranium*, which, in the young animal is capable of being divided into about thirty separate pieces. It contains a large cavity, in which the continuation of the spinal cord, the *brain*, is lodged, and externally, in the front, presents two hollows, in which the *eyes* are placed. These hollows communicate, posteriorly, by large openings with the cavity of the skull, and below these, in the front, there are two openings (*the nostrils*) which consist of a canal which is divided into two parts by a plate of bone, and almost entirely filled with soft, thin, and curiously twisted plates of bone. Behind the cavity of the nose is the perforated sieve-like bone (*ethmoid*). There are also numerous openings, by which nerves and blood-vessels proceed from, and communicate with, the cavity of the skull.

The bones just described are those which are first formed. It is only at a later period of the animal's growth that those of the second division make their appearance, viz., those of the fore and hind extremities. The fore extremity commences with the shoulder-blade, and the hinder extremity with the hip-bone. The shoulder-blades are placed loose on each side of the chest, and are kept in their place by muscles; the hip-bones, on the contrary, are connected below, and also above, with the sacrum, and form an irregularly-shaped circle of bone, called *the pelvis*. In man, and all those animals which use the upper extremities for grasping, there is a bone called the *clavicle*, or collar-bone, which is wanting in the Animals of the Farm. It is connected with the arm and breast-bone, and is frequently broken when any violent shock is given to the arm, as when the weight of the body is thrown upon it in falls. It would, therefore, if present, be continually exposed to fracture in the violent motions of the horse in galloping and leaping. Nature, however, protects the fore legs of the horse from injury by an admirable arrangement, by which the legs, instead of being closely bound to the trunk by a band of bone, are connected with it merely by powerful muscles, so that the trunk is, as it were, suspended between the legs. The shoulder-blade, or *scapula*, exerts great influence on the motions of the animal. It is a triangular

bone, and is furnished with an appendix of cartilage, which increases the surface which it affords for the attachment of muscles, and also presents a hollow, called the *glenoid* cavity, in which the head of the *humerus*, or arm bone, is received. When the scapula is long and obliquely plac'd, as in the horse, the muscles of the forearm attached to it are enabled to exert a powerful action.

The forearm consists of two bones, named the *radius* and *ulna*. In man these bones are separate, and the radius rotates, but in the horse this motion is not required, and the two pieces are united together, except at the upper part. The ulna is connected with the wrist, which in the horse is usually termed *the knee*. It consists of seven distinct bones closely bound together (*the carpal bones*). In the horse, one of these bones is greatly enlarged, and the bone which in man corresponds with it, termed the metacarpal bone of the middle finger, is also greatly developed. In man, the radius being moveable, the hand is capable of a great number of delicate movements, and of being turned completely round. In all quadrupeds, however, the union of the two bones of the forearm prevents these motions, and that part of the wrist and the bones below it, which corresponds to the back of the hand in man, is permanently turned outwards.

PART X.

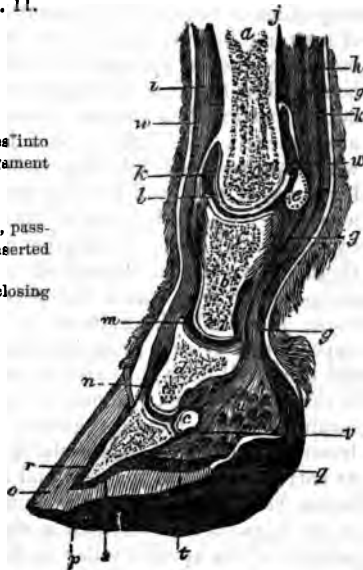
THE SOLID FRAMEWORK (CONTINUED).

In the Animals of the Farm, as has been stated, the fore extremities present bones corresponding to those which we find in the arm, forearm, and wrist in man—*humerus*, *ulna*, *radius*, and *carpal* bones. The radius and ulna, however, which, in the forearm in man, are separate, are, in the lower animals, firmly united together, and one of the bones of the wrist is also greatly increased in size. In man the hand consists of five bones, called *metacarpal* bones, to which are attached the bones of the fingers, *technically* named *phalanges*. In the horse and ox we

observe a remarkable simplification and modification of the bones which extend from the wrist. Thus in the horse the number of the metacarpal bones is reduced to three, that which corresponds to the metacarpal of the middle finger being greatly enlarged and lengthened, so as to form a strong upright pillar of bone, called by veterinarians "the cannon-bone" (*Fig. 11, a*), while those corresponding with the second and fourth fingers are stunted to a comparatively small size, and attached to the cannon-bone,

Fig. 11.

- a* Metatarsal or cannon-bone.
- b* Greater pastern.
- c* Navicular or shuttle-bone.
- d* Lesser pastern.
- e* One of the sesamoid bones into which the suspensory ligament (*j*) is inserted.
- f* The coffin-bone.
- g* The flexor perforans tendon, passing down the leg to be inserted into the coffin-bone.
- h* The capsular ligament enclosing the fetlock joint.
- i* The fetlock joint.
- m* Pastern joint.
- n* The coffin joint.
- o* The horny crust.
- p* The horny sole.
- q* The frog.
- r* The sensible laminae.
- s* The sensible sole.
- t* The sensible cushion.
- u* The cushion.
- v* Navicular joint.



SECTION OF THE FOOT AND PART OF THE LEG OF THE HORSE.

constituting the "splint bones" of the farrier. Extending downwards from the cannon-bone are three bones corresponding to the phalanges of the middle finger, but greatly altered in size and form. These receive special names. The first being called the greater pastern (*Fig. 11, b*), the second, the lesser pastern (*Fig. 11, d*), and the third, which supports the hoof, the coffin-bone (*Fig. 11, f*). Behind the coffin-bone there is also, in the horse, a

narrow bone, the navicular (*Fig. 11, c*), which has been fancifully named the shuttle-bone. There are also two little bones, the sesamoid bones, placed on the fetlock, which serve to throw the tendon of the foot which moves over it farther from the centre of motion (*Fig. 11, e*).

The posterior differ from the fore extremities in being connected by a joint with the bones of the trunk, the thigh bone, or *femur*, being received into a cup-like cavity in the hip-bone. The head of the femur, the whirl-bone, which is round, is secured in its place not only by the deep sides of the cup and powerful muscles, but by means of a strong ligamentuous cord, which extends from the bottom of the cavity, and is inserted into the head of the bone. The femur is the largest and strongest of all the bones, and exhibits various projections to which muscles are attached. Its inferior end forms two prominences, which are received into depressions in the head of the leg-bone, or *tibia*, and between these prominences there is a groove in which the bone of the knee, called "*stifle-bone*" by farriers, glides. The leg-bone is usually termed the thigh. Like the corresponding part in man, the leg is composed of two bones, the *tibia* and *fibula*; but in the horse the fibula is reduced to a very small size, and appears merely as a projection springing from the back of the tibia. It does not exist in the ox. Below the tibia is the tarsus, or hock, consisting of six bones of irregular outline, firmly bound together, but so arranged as to lessen the effects of violent shocks. It may be regarded as corresponding to the heel and instep of man, and the bones below to those of the human foot, all the bones in the horse being increased in size, and made to form a portion of the upright pillar of the limb. The large bone, which extends from the hock, corresponds to the metatarsal bone of the third toe, just as in the fore extremity we have seen that the cannon-bone corresponds to the metacarpal of the middle-finger; while jointed to this metatarsal, we have also the three phalanges of the same toe. The splint bones extending from the hock on either side, represent the metatarsal bones of the second and fourth toes.

In the ox, the cannon-bone is not formed by the enlargement of a single metatarsal, but is made up by the

consolidation of the metatarsals of the third and fourth toes, and shews two distinct protuberances or condyles at the lower end, to which are connected the phalanges of the third and fourth toes; and in the "false hoofs" of the ox we find the rudiments of the phalanges of the second and fifth toes.

HOW THE WASTE MATERIALS ARE REMOVED.

By the circulation of the blood, as we have seen, the nutrition of the body is accomplished. The process by which, from the blood, new materials are added to the animal structure, is termed *assimilation*; and the more abundant the materials carried to an organ, the more rapid will be its growth and activity. When the supply of blood is arrested, the organ wastes and dies. In youth, assimilation exceeds waste, hence the body increases in size; if more material be supplied than is necessary for nutrition and growth, fat is deposited; if less be given, emaciation ensues. The separation from the blood of the products of the waste of the body, consequent upon the various processes of the system, and also of certain liquids which are to serve for the performance of important functions, is of no less consequence to the continuance of life than the assimilation of new material. Nutrition and excretion may be regarded as opposed to each other in the system. The more active the excretions, the less will be the amount of flesh formed and of strength exhibited. The more milk, perspiration, and wool produced, the less will be the amount of flesh or fat formed. The matters separated from the blood are divided into secretions and excretions.

1. *The secretions* are such separated materials as are required for the performance of certain offices in the economy of the animal, as the saliva and the pancreatic juice, the mucus, &c.

2. *The excretions* are those substances which are composed of the effete worn out materials of the body, or which are useless for nutrition, and which, for the continuance of health, must be removed. Thus, the useless saline and mineral matters carried into the blood, and the waste matters which are soluble in water, are excreted in

the urine, while the gases are removed by the lungs, and the carbonaceous matters of the food, and of the decomposed tissues which have not been converted into gaseous forms, are removed by the intestinal canal, or by the skin or kidneys in sweat and urine.

The separation of the secreted and excreted matters from the blood is accomplished by simple physical laws, by exosmose and endosmose, in certain bodies termed glands, which may be regarded as consisting of a finely granular structure, intimately penetrated with capillary blood-vessels, and furnished with a tube, or duct, as it is called, for conveying away the matters filtered from the blood. In some cases, the secreting organ is furnished with a receptacle in which the secretion is stored up, so as to be employed or discharged periodically. Thus, the bile is stored up in the gall-bladder, the urine in the bladder.

The chief organs for the separation of the soluble saline matters of the food and tissues are the *kidneys*, which are two red-coloured bean-shaped bodies placed in the loins, one on each side of the spinal column, embedded in fat. The outer or *cortical* portion of each kidney consists of a granular glandular substance, into which the blood is carried by a large branch of the aorta (the renal artery), and the separation of the secretion termed urine is effected. The urine, when separated, is carried through converging tubes, placed more towards the interior, and arranged in bundles, and these pour their contents into a receptacle called the pelvis of the kidney, from which it is conveyed through a long tube, termed the *ureter*, to a reservoir—the *bladder*—placed in the cavity of the pelvis, in which it is retained, until by over-distention, or the stimulus of its contents, the voluntary contraction of its muscular coat causes its discharge. This is effected through a tube—the *urethra*,—which in the female animal is short and wide, but in the male close and narrow.

Connected with the kidney is what is termed the *renal capsule*, placed over each kidney, the use of which is not well understood; but these bodies are much larger in the foetus than in the adult, and are probably connected with the peculiarities of foetal circulation. As the urine con-

tains the waste matters of the food and tissues, its composition will be influenced by the habits and food of the animal. The urine of carnivorous animals is acid and transparent, while that of herbivorous animals is alkaline and turbid. It contains the oxidized remains of the body which are incapable of assuming the gaseous form. Thus we find in it urea, formed from decaying muscle, and sulphates and phosphates derived, the former from the sulphur of the food and tissue, and the latter from the phosphorus of the nervous substance.

The nitrogenized compounds which are discharged by the kidneys are urea and uric acid. About half an ounce, or 270 grains, of the former, and about 8 grains of the latter, is the average daily amount, according to Liebig. When a sufficient amount of oxygen is conveyed in the arterial blood to the worn-out tissues, the soluble compound urea is produced; but if the supply of oxygen be less abundant, the nitrogen compounds are changed into the less soluble uric acid, as is observed in the slowly-respiring *boa constrictor*, which discharges its urine in a dense solid form, and consisting chiefly of a compound of uric acid and ammonia; while in the rapidly-respiring and carnivorous *tiger*, the urine exhibits merely traces of uric acid.

PART XI.

THE SKIN.

COVERING the bony framework and muscular layers of the animal body is the *skin*, or *hide*. This covering possesses a highly complicated structure, and its condition exercises a most important influence on the health of the animal. That part of it exposed to the air is generally covered with hair; but penetrating into the interior of the body by the openings of the nose, mouth, anus, and urinary organs, we find, continuous with the external envelope, a delicate lining membrane, which is termed, from being constantly moistened by a slimy secretion, the mucous membrane. The external envelope, or skin, may

be described as consisting of three parts or layers, which may be separated by macerating a piece of skin in water. The internal and most dense of the three laminæ is the *true skin, cutis vera*. This layer differs very much in thickness and strength in different parts of the body, being generally thin in the vicinity of the different apertures of the body, and thick and strong on the back. It is composed essentially of a close structure of cellular tissue, penetrated by the minute hair-like branches of the blood-vessels and nerves, and possesses great sensibility. In some situations this sensibility is exceedingly delicate, as in the lips of the horse, the snout of the pig, the sensitive proboscis of the elephant, and the fingers and toes of man. In these situations, the nerves are found forming small conical elevations. It is this layer of the skin that supplies us with leather; and the preparation of that useful article, in so many ways serviceable to man, depends upon the property which the gelatin, of which the tissue of the true skin consists, possesses of combining with the tannin of the astringent barks used by the tanner to form a solid insoluble compound, which, enclosed within its meshes, renders them impervious to moisture. To the outer and most vascular portion of the true skin, a delicate network of soft round cells, containing a slimy liquid, is attached. These cells constitute the *rete mucosum*. The slimy cells of this layer, on its external part, are found gradually to assume a flattened shape, and form a smooth surface, and in the parts of the skin exposed to the air, become dry and scaly, constituting what is termed the *epidermis, cuticle, or scarf-skin*.

At the lips and other apertures of the body the tough and opaque epidermis becomes modified into the delicate and transparent *epithelium*. Under the microscope, this delicate structure is seen to be made of minute scales placed one over the other, just as figs are packed in a box. By this arrangement great looseness and openness of texture are produced, so that their shape can readily be modified by the various agents which come into contact with them—especially by water. The epidermic scales lie on the papillæ of the mucous membrane, whence their name, from the Greek, *epi*, upon, and *thelai*, papillæ.

The epidermis presents, in its thickness in the different

parts of the body, still more striking differences than the true skin. At the orifices of the body it is extremely thin, delicate, and transparent, but in other parts it becomes thick, opaque, and hard, and wonderfully altered in appearance, as in the horns and hooves of the cow, and in the nails and hairs of other animals, which are regarded as merely modifications of this membrane. On the feet of many quadrupeds the epidermis forms balls, and on the tails of rats and mice it is converted into distinct scales.

While the true skin is highly vascular and sensitive, the cuticle, at least in its external layers, is destitute of vitality. Thus the hair may be cut, the hooves pared, and the wool shorn without any pain being experienced by the animal. It is, in fact, during life, constantly being separated and renewed again by the deposition of new materials. (By washing the skin and currying horses this separation may be observed.)

The true skin, we have seen, is penetrated in all directions by minute vessels conveying blood. These give it a reddish colour, which, in those parts where it is covered by transparent cuticle, give the surface of it the usual tinge characteristic of flesh.

The cuticle itself, not merely in animals and men with light-coloured skins, but in the black horse and the dark American, is entirely destitute of colour. Frequently, however, the cells of the *rete mucosum* are found to contain certain pigments rich in carbon and iron, which, so far as known, are found to possess either a yellowish, a brown, or a brownish-black colour, and these show through the transparent scarf-skin, and produce, according to their development, the various shades of colour which the skin presents. Yet, as already stated, the cuticle in all these cases remains colourless, with the exception, however, of those modifications which assume the form of hair and horn, and in which it is found that the colouring matter remains unchanged, preserving its proper tint. Sulphur is also a constituent of hair, and upon this fact is based the use of leaden combs, salts of mercury, &c., to give a dark colour to hair.

The production of these colouring matters is considered to be in some unknown way connected with the health

and vigour of the animal, those with light-coloured skins being observed to be usually more delicate than the dark-coloured. Heat and sunlight also exert a remarkable and well-recognized influence on the colour of the skin;—thus, in winter the bear and other animals of the polar seas have white skins, which in summer change to a dusky hue. The hair of the common squirrel, which is of a deep red colour in summer, changes to a greyish-blue tint in winter.

The great importance of the functions performed by the skin of animals is well known. The examination of the cuticle shows that it is penetrated by minute canals, which communicate with small glands in the true skin, by which the watery part of the blood, and also carbonic acid, ammonia, butyric acid, and certain not yet fully investigated odorous principles are separated and conveyed to the epidermis, and there gradually evaporated into air in insensible perspiration, or, when their action is increased, collected in drops of moisture, which we term sweat. The length of the tubing employed in this water-secreting apparatus is in man about twenty-eight miles!*

The uses of the cutaneous secretion are, 1st, to regulate the temperature of the body. In this office it co-operates with the lungs. 2nd, It is the medium through which certain substances are eliminated from the body; and the observations which have been made, both on man and animals, show that the suppression of perspiration by sudden chills exerts a most pernicious influence, and leads to the conclusion that the substances which are thrown back on the system exert in such cases changes in the metamorphosis of the blood, and on the functions of the various organs, which produce morbid phenomena. The skin in a healthy state exerts a most remarkable activity in separating certain odorous substances from the system;—thus, turpentine, musk, and other strong-smelling substances taken into the body, rapidly communicate their peculiar odour to the cutaneous secretion. In fact, if we

* The number of the sweat-glands in an adult man of average size is supposed to be 2,300,000, and the length of each of these tubes one-fifteenth of an inch (*British and Foreign Med. Chir. Rev.*, 1859, p. 349). We can, therefore, easily understand how labourers in gas works lose $3\frac{1}{2}$ lbs. weight by cutaneous and pulmonary exhalation in less than an hour (Dr. Southwood Smith).

were to varnish over the entire surface of the body of an animal with some impervious coating, its death would follow. These facts, therefore, connected with the history of the skin will, I trust, serve to impress upon your minds the necessity of careful attention to its preservation in a healthy condition. This, in the treatment of animals, is to be accomplished, 1st, By the frequent use of the curry-comb and rubbing, by which the obstruction of the sweat canals will be prevented; and 2nd, By the use of covers to prevent sudden chills after the horses have been exposed to severe work.*

The skin of animals serves both to protect and to bind together the different parts of the body. For these purposes it is, by its peculiar structure, admirably adapted. It exhibits a striking combination of strength, flexibility, and elasticity. Where firmness is required to resist strains it adheres closely to the bones, as where it covers the knees and pasterns of the horse, while in other parts, where free motion is required, it hangs in loose folds. Where but little resistance to external pressure is needed, it is found thin and fine, but in those parts where strength is necessary, it forms a thick and tough covering. Studded in every part of the extensive surface which it presents with glands which secrete the perspiration, and also with the sebaceous glands (Lat. *sebum*, suet), which pour out an oily secretion essential to the healthy condition of the integument itself, it must be regarded as an organ of very great importance.

I have already alluded to the hair which covers the skins of animals, and the hooves and horns as appendages of the cuticle. All these formations are to be regarded as merely modifications of the epidermis. We shall at present confine ourselves to the consideration of the hair and wool of our domestic animals, and proceed, in the first place, to describe the peculiarities of their structure, which are made known to us by microscopic investigations.

That part of a hair which projects beyond the skin is termed its *shaft*, and, when placed under the microscope,

* Krause calculated that in twenty-four hours there are excreted by the sweat in an adult male 791.5 grains (12 oz. nearly) water, 7.98 of organic and volatile matters, and 2.68 of mineral substances.

is found, in the hair of the horse, and dog, and many other animals, to form a tube surrounded by a layer of delicate cells which overlap each other so as to present an imbricated appearance, like that presented by the tiles on the roof of a house. When the shaft of the hair is traced into the skin it is found to terminate in a bulbous extremity, and to be inclosed in a small bag or follicle formed by an involution of the cuticle. In the bottom of this bag, which is also, like the hair, expanded into a bulb, the hair is fixed, while about the upper third of the follicle two small openings from tubes connected with little round glandular bodies,—the sebaceous glands,—are to be observed. These glands secrete an oily matter which keeps the hair smooth and glossy, and protects it from moisture. The hair is formed of cells like the cuticle itself, but while the epidermic cells become gradually flat and scaly as they approach the surface, the cells composing the hair, as they extend from the bulbous root, are condensed and elongated into fibres, except in the external layer, in which they are arranged in delicate scales, which overlap, as already stated, in an imbricated form. The colouring matter of the hair is developed in the membrane at the bottom of the bulb, in the form of minute granules, which are usually chiefly condensed in the axis of the hair, and produce, as they pass upward in the shaft, a dark central tract. In some hairs, as in those of the cat and mouse, a number of centres of colouring matter are observed, on making a transverse section.

Wool, which possesses so great importance as the raw material of one of the leading manufactures of England, and which, from the earliest times, has been employed both by civilized and uncivilised people as clothing, is regarded by some writers as possessing peculiarities of structure which distinguish it from hair, and give it those valuable *felting* qualities by which its filaments, when mixed together and pressed, interlace so as to form a coherent fabric, as may be seen by visiting a hat manufactory.

The differences which exist between the characters of wool and hair are, according to Schleiden,—1st. That wool is finer; 2nd. It is not in straight, stiff filaments, but spiral; and, 3rd. It contains less colouring matter. A *peculiar character* of wool, also, is that the filaments

throughout their entire length, possess the same thickness, and are, one with the other, of like thickness, while hairs exhibit great difference in thickness in different portions of their lengths, and also as compared with one another. The outer covering of cells, which forms the *cortex* or bark of hair, presents an imbricated appearance, and when viewed by the microscope, gives the hair the appearance of being furnished at the sides with toothed margins. The serrations, or toothed margins, are much less marked in wool than in hair.

PART, XII.

ON THE COMPOSITION OF MILK AND THE METHODS EMPLOYED FOR ESTIMATING ITS VALUE.

COMPOSITION OF MILK.

THE milk of the cow, when just drawn from the udder, is usually very slightly alkaline, and has a somewhat sweetish taste, but it rapidly becomes neutral, and, on keeping, gradually acquires at first a faint, and, after some time, a strong acid reaction and sour taste. By keeping, also, other important alterations are produced in the composition of the fluid; thus it loses its homogeneous appearance, and an opaque layer of yellowish-white fatty matter, the *cream*, collects on its surface, leaving the liquid below of a somewhat bluish tinge. If the cream be removed, "the skimmed milk," in the course of some time, becomes acid, and is separated into two portions—a curdy matter, which falls to the bottom of the vessel, and a watery liquid, "the whey." These changes, it will be seen, are partly chemical and partly mechanical, and for their investigation we require to combine with chemical means the use of the microscope. The chemical examination of milk makes known to us the interesting fact, that that fluid may be regarded as an example of a perfect food, containing all the constituents required for animal nutrition; thus it discovers in it an oily matter, *butter*; and a saccharine substance, the *sugar of milk*; a nitrogenised flesh-forming compound, *casein*, which has the same composition as the fibrin of wheat; the *phosphates* from which bone is built up; and the *saline* compounds which exist in blood. It is shown to be a store richly furnished with the raw material of beef and blood, of fat and bone. The proportions in which these materials

exist in the milk of different animals is found not to be the same, and, as is well known, both the quality and quantity of cows' milk are subject to considerable variation. The following analyses of cows' milk will show its usual composition. No. 1 gives the average composition of samples of milk analysed in France; No. 2 and 3, of milk supplied to the Union Workhouse, Belfast, and examined in my Laboratory; No. 4, of cows' milk, and No. 5, of human milk, examined in Germany, by Haidlen.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Water,.....	87.40	90.18	90.67	87.3	89.2
Casein and	} 3.60	{ 3.40	{ 3.45	5.1	3.1
Insoluble Salts,...					
Butter,.....	4.00	2.30	3.27	3.0	3.4
Sugar of Milk,....	{ 5.00	3.51	{ 2.08	4.6	4.3
Soluble Salts,....					
		0.24	0.17		

The specific gravity of cow's milk averages from 1,025 to 1,031, that of water being 1,000. The following analysis by Haidlen will serve to show the constituents which it is capable of supplying when employed as food. 1000 parts contained—

Water, ...	873.00
Butter, ...	30.00
Milk Sugar, ...	43.90
Phosphate of Lime, ...	2.31
Phosphate of Magnesia, ...	0.42
Phosphate of Iron, ...	0.07
Chloride of Potassium, ...	1.44
Chloride of Sodium (common salt), ...	0.24
Soda, in combination with Casein, ...	0.42

1000.00

The peculiar kind of sugar (*lactin*) which the milk of herbivorous animals* contains resembles grape sugar in composition, and may be regarded as consisting of 24 equivalents of carbon in combination with 24 equivalents of water. In some countries it is prepared in considerable quantities from milk. It is very hard and gritty, and not so sweet or soluble in water as cane sugar; but its solution is capa-

* The milk of the carnivora contains no sugar, but is richer in casein and butter than that of herbivorous animals.

ble of undergoing decomposition on the addition of a ferment, and of producing alcohol. In Circassia, Mr. Spencer tells us that fermented milk is used as a common beverage under the name of *skoä*. It is prepared by boiling milk, and adding to it some fermented milk, reserved from a previous brewing, and forms an agreeable and exhilarating drink.

The kind of food consumed by the animal, experience has fully shown, exercises an immediate and important influence both on the quantity of milk and the proportion of butter which it contains. Not only, however, is the quantity of the butter produced dependent upon the food, but its qualities, and especially its flavour, are found to be materially influenced by the treatment of the animal. Thus, as is frequently observed, the stall-fed cow supplied chiefly with roots, such as potatoes, yields a white granular butter, which, when oleaginous food, such as oil-cake or rape, is substituted, becomes oily and of a comparatively unpleasant odour; and, in some cases, the excess of oily matter in the milk renders it impossible in churning to separate the butter in a solid form. In the early months of spring, again, the bitter taste which the young herbs of the fresh grass imparts, is also well known; and in winter, when turnips form a chief part of the food, the unpleasant flavour which the butter acquires, and which renders it to many persons so exceedingly disagreeable, is familiar to every farmer. Fortunately this turnip-taste may be altogether, if not entirely, prevented by extreme carefulness on the part of the dairy keeper to secure perfect cleanliness in every operation connected with collecting the milk and preparing the butter. It is believed by many experienced dairy farmers, that the peculiar disagreeable odorous principle which communicates the turnip-taste to butter, is developed by the milk coming into contact with some decomposing decaying matter which has been suffered to remain in the imperfectly cleansed vessels of the dairy, and which acts as a ferment; at all events, absolute cleanliness is a safe preventive. But even when the taste has been communicated it may easily be removed by simple means. The addition of a small amount of saltpetre to the milking pail has been found effectual; but the most certain means is to add to the milk, when taken from the cow, a teaspoon-

ful or two of a solution made by pouring half a pint of rain water upon a tablespoonful of the substance sold as bleaching powder—chloride of lime. This solution, however, should not be relied upon when too long made, but should be freshly prepared.

Butter, as prepared in the dairy, contains, mixed up with it, small proportions of the other constituents of milk, and upon these its agreeable taste depends. It is, however, owing to the presence of these foreign substances, as they may be termed, that butter, when exposed to the air, gradually undergoes changes by which it acquires a disagreeable taste and smell, and becomes, as it is termed, *rancid*. These changes depend chiefly upon the action of the peculiar nitrogenized constituent of milk, casein, which, like all substances rich in nitrogen, is exceedingly liable to decomposition, and by its decay is found to dispose the other matters also present to form volatile and disagreeable smelling acid compounds (butyric acid, &c.).

The proportion of casein which butter contains is shewn by the following analysis of a French chemist, M. Quevenne. 100 parts he found to be composed of—

Pure Butter,	..	..	..	..	..	77.50
Water,	..	..	..	..	..	20.90
Casein,	..	..	..	..	..	1.60
						100.00

The acid compounds formed in rancid butter are volatile and soluble in water ; so that by heating it and washing it completely with water its disagreeable taste may be entirely removed. The various plans proposed for preserving butter depend for their success either upon protecting it from the influence of the air, or by using antiseptic substances, as salt and sugar, which prevent the decomposition of the casein ; or upon heating it so as to entirely remove the cheesy matter which disposes it to spoil.

The quantity of milk which a cow will yield is not merely influenced by breed, food, and treatment, but is different at different periods ; from eight to twelve quarts daily may be regarded as the ordinary produce. The following table, from observations made at the Albert School Farm, near Dublin, will be found interesting :—

COMPARATIVE PRODUCE OF MILK OBTAINED FROM SEVEN COWS OF DIFFERENT BREEDS.

No.	BREED.	DATE OF CALVING.	Total quantity of Milk obtained after calving.		Average Daily Produce for 6 Months, in Quarts.		Average Daily Produce for 9 Months, in Quarts.		OBSERVATIONS.
			Gallons.	Gallons	Quarts.	Quarts.	Quarts.	Quarts.	
1	Pure Short-Horn,	28th March, '59,	366	437	7-95	6-50	6 years old, would fatten to 9 cwt.		
2	Half-bred do.,	25th do., '59,	425	521	9-24	7-86	9 Do.	Do.	Do.
3	Irish,	26th April, '59,	379½	470½	8-25	7-11	10 Do.	Do.	6 cwt.
4	Ayrshire,	18th March, '59,	379½	516	8-25	7-67	6 Do.	Do.	7 cwt.
5	Devon,	19th April, '59,	345	423	7-50	6-29	10 Do.	Do.	Do.
6	Kerry,	1st August, '59,	276	352	6-00	5-22	6 Do.	Do.	4½ cwt.
7	Alderney,	3rd March, '59,	345	420	7-50	6-24	8 Do.	Do.	5½ "

The casein in milk is held in solution by soda, but the butter is merely suspended through it in a finely-divided condition; milk, in fact, resembles an emulsion, in which a thin, colourless, and transparent liquid is rendered opaque, and of a white colour, by the suspension in it of extremely minute particles of fatty matter.

One of the most important constituents of milk, with reference to its value for human food, is the nitrogenised substance, casein. The proportion of this compound is found to be influenced by the kind of food supplied to the animal, and to be increased by the use of substances rich in nitrogenised compounds. According to Boussingault, the average amount in cows' milk ranges from 3 to 4 per cent., other observers have, however, given a much higher average, Playfair, in England, estimating it at 4.16, while Simon, in Germany, raises it to 7 per cent.

In milk, casein exists in two conditions, partly in solutions and in part forming transparent capsules which invest the globules of fat and keep them from coalescing, as occurs when they consolidate into butter. The existence of a delicate membrane investing the fat globules, which was asserted to exist by the French chemist Raspail, was not until lately demonstrated. If a thin layer of fresh milk be spread on a piece of glass, and examined by the microscope, it is observed, like blood, to be composed of minute capsules or globules, swimming in a colourless and transparent liquid. These globules consist of the oily matter of the milk, surrounded, as stated, by a capsule of casein. The microscope, however, does not show us this transparent investing membrane until chemical means, as a few drops of acetic acid, are also employed in the investigation, when the globules become distorted, and drops of fat can be seen emerging from them.

Their presence may also be most clearly discovered by a simple and very interesting experiment. If you place a piece of butter in ether, you will find that it readily dissolves, forming a clear solution. Even if you were to mix some water with the butter, and add a sufficient quantity of ether, it would be dissolved, and could be entirely removed from the water, as the ethereal solution of the butter would float, forming a distinct layer. If now the fatty matters in milk were merely suspended in it, without being

inclosed in capsules, ether should dissolve them and leave the milk a transparent fluid ; but if you agitate some fresh

Fig. 12.

GOOD MILK.

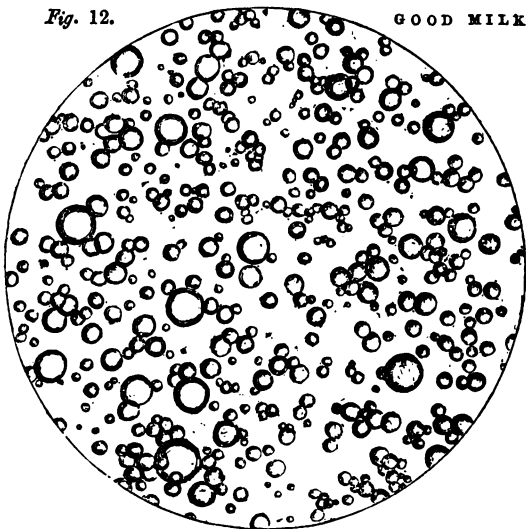
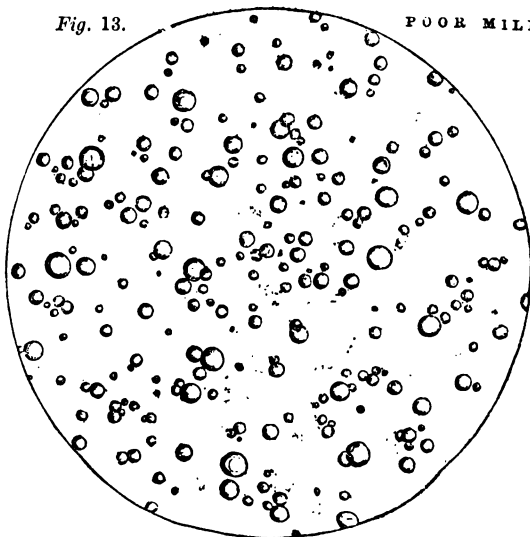


Fig. 13.

POOR MILK.



milk with ether, you will find that merely traces of fat are dissolved. The fat in milk must therefore, it is clear, be enclosed in cases which the ether cannot dissolve, and that this is the case is proved by adding to the milk some substance in which the capsule will dissolve, as caustic potash, or an alkaline carbonate, as carbonate of soda, when it will be found that ether acts upon it as upon a liquid in which particles of butter are merely suspended (Lehmann). In the operation of churning the delicate investing membranes of the fat globules are ruptured, and the granules of fat allowed to coalesce.

ESTIMATION OF THE QUALITY OF MILK.

It has already been stated that the proportion of the constituents in milk is subject to considerable variation. In the sale of milk, also, complaints—and not without good foundation—are made that its nutritive value has been lessened by admixture with water, and that occasionally a very inferior article has been made to assume the appearance of genuine milk by the fraudulent addition of various ingredients. Various methods have been proposed for the detection of these frauds, and also for estimating the quality of milk; and, as the subject is of very great importance, it will be useful to notice the means adopted in such examinations, to consider their value, and to point out the precautions requisite for their successful application.

Three different methods have been proposed for estimating the quality of milk, viz., the determination of its specific gravity, or the weight of a certain measure of milk as compared with the weight of an equal bulk of water; the direct measurement of the amount of cream which it affords; and the determination of its transparency.

Milk, as already observed, may be regarded as an emulsion in which a fatty matter finely divided is suspended in water, and in which there is also dissolved sugar, casein, and a small amount of saline substances. Its specific gravity will therefore be different from that of pure water, and be influenced by the quantity of its constituents present. Butter, as you are aware, is lighter than water; so a sample of milk will be found to show a lower specific

gravity in proportion to the increase in the quantity of oily matter which it holds in suspension. The specific gravity of water being 1000, that of fresh butter is only 0.902. The instrument used for obtaining the specific gravity of milk resembles in its shape the common hydrometer which the distiller employs in ascertaining the strength of spirits. It is formed of glass, and marks on the stem indicate the depth to which it will sink when placed in pure milk, and also in mixtures of pure milk and water. A hydrometer of the kind used by chemists for ascertaining the specific gravity of liquids heavier than water may also be employed in the examination of milk. The greater the proportion of cream present the lower will be the specific gravity of the milk, and Schübler found by experiment the following correspondence between the specific gravity of the milk and the per centage of cream contained in it. Thus, when the milk was—

Specific gravity	1.0309	it afforded	19	per cent. of cream.
"	1.0318	represented	16	" "
"	1.0327	"	13	" "
"	1.0334	"	9	" "
"	1.0340	"	7	" "

Though the hydrometer may serve to indicate the value of milk when we are certain that no water has been added to it, yet it affords us no assistance in cases of adulteration. In the first place, the specific gravity, even of pure milk, varies very much at different seasons; and, secondly, the vendor who abstracts a portion of cream from milk, and thus increases its density, usually takes care to add some water, which renders it difficult to detect the fraud, the specific gravity of water being only 1000, while that of milk of ordinary quality is 1032. Thus even when the milk has been robbed of its valuable cream, it may, by the addition of water, be made to present the density of the genuine article.

The chief method adopted in this country for the examination of milk, is by the measurement of the quantity of cream which it is capable of affording. For this purpose a simple instrument, termed the *lactometer*, or *milk gauge*, is used, which consists of a tall and narrow glass, usually

about 10 inches in length, and an inch in diameter, and graduated into 100 equal parts, the scale commencing at the top of the glass. When milk is poured into the glass up to the first mark, and allowed to rest for 24 hours, it will be found that the cream at the expiration of that time has separated, forming an opaque layer on the surface of the milk. The thickness of this layer, measuring from the division where the opacity commences to the surface of the cream, is ascertained by reference to the figures engraved on the side of the glass, and the number of degrees observed indicate the per centage of cream in the milk. A number of these tubes are required for use in the dairy, and may be conveniently placed in a wooden stand, so as to admit of the comparative examination of several samples of milk; they may be procured at the glass house, or from any manufacturer of chemical apparatus. Though this form of instrument is recommended by its simple construction, and the apparent accuracy of its indications, yet to obtain perfectly correct results several precautions are necessary, and even when properly employed its results are to be regarded as only comparative. It affords us no information with respect to the proportions in which the casein and other constituents of milk are present, and gives us merely an approximation to the actual amount of cream which the milk contains. From the circumstance that the lactometer is at present very generally employed in this country, and that it has been adopted in estimating the quality of the milk supplied to the Workhouses, it will be useful to consider the causes which influence the accuracy of its indications.

1. When milk is taken from the cow and placed in the collecting pans it exhibits no acid reaction; that is, it has no sourness, and does not, like acid solutions, render the blue test paper of the chemist red. But very soon it becomes slightly sour, and it is found that the production of acidity is promoted by whatever elevates the temperature of the milk. The quantity of acid gradually increases so much that it coagulates the casein, and when the souring of the milk is quickly produced, from the vessels containing traces of sour milk, or from an elevated temperature of the season or of the milk-room, it will usually be observed that the amount of cream separated will not

be so great as when the souring and consequent coagulation is retarded. The spongy mass which the coagulated casein forms entangles some of the particles of cream, and prevents their ascent to the surface of the milk. The influence, therefore, which the slow or rapid coagulation of milk exercises in promoting or retarding the separation of the cream, enables us to explain the discordance in the results obtained in the use of the ordinary milk gauge, and shews us how much the per centage of cream, as indicated by the tube in a sample of milk, may depend upon the rapidity or slowness of its coagulation. It also explains the beneficial effects of the practice of keeping the milk in shallow vessels at a moderate temperature, so as to avoid its becoming too rapidly sour, and to favour the more easy ascent of the butter globules. You can readily understand, from the statement just made, how it may sometimes happen that a sample of fresh milk placed in the tube immediately after milking, will yield a larger per centage of cream than the milk from which it has been taken when examined after it has been carried for several miles and exposed to the action of the air, and also agitated in contact with the air contained in the milk vessels, and probably brought into contact with vessels containing some traces of acidity.

2. It is a fact well known to milkers, that the last portion of the milk drawn from the udder is much richer in butter than that which is first drawn, while the other constituents maintain the same relative proportions. A merely mechanical cause is commonly assigned for this difference of composition by agricultural writers, and you will find it stated that it is to be ascribed to the fatty matter accumulating upon the surface of the milk in the udder, while the more dense watery portion will be collected in the under part, and consequently be first drawn away.

But this explanation is no longer admissible, as it has been found by experiment that the same thing prevails with respect to woman's milk drawn in fractional portions from the breast. As, however, the fact is certain that the milk which is last drawn is invariably richer in cream than that which is first drawn, it is obvious that in proceeding to estimate the amount of cream which the milk

of a cow is capable of affording, our samples should be taken from the entire quantity of milk obtained, after taking care to thoroughly mix together the various portions.

From the observations which have been made, the following practical conclusions with respect to the use of the lactometer may, I conceive, be drawn:—1st. That it affords purchasers a very uncertain method of calculating the actual value of milk, as its indications are influenced by temperature, and also by the changes which the milk may have undergone when brought from a distance. 2nd. As it is incapable of indicating the amount of the valuable muscle-forming casein, or of the sugar and saline matters which are essential constituents of milk, it cannot be regarded as affording us information with respect to the actual value of milk as an article of food.

3. That as the thickness of the layer of cream which a sample of milk may throw up in a given time, will be influenced by the length of the tube, the temperature to which it is exposed, the portion of the milk examined, and the influence of mechanical and chemical causes, it cannot be regarded as indicating correctly the actual richness of the milk in cream; and it follows that the purchaser is not entitled to consider a sample of milk as deficient in cream, even when it fails, when tested in the Workhouse, to give the same per centage as when examined by the contractor.

The third method of distinguishing the value of milk is based upon the fact, that the opacity of milk depends upon the corpuscles of fatty matter which are suspended on it, and that consequently the more cream it contains, the greater will be the obstacle opposed to the passage of the rays of light. An ingenious, but rather costly instrument, called a *Lactoscope*, has been invented in Paris, by Donné, for the purpose of accurately determining the degree of transparency which the milk possesses. The lactoscope consists of two tubes, one of which may be pushed into the other like the joints of a telescope, and the end of each tube is closed with glass, so that when milk is poured into the outer tube by a small opening on the side, by pushing in the inner tube, a layer of milk of any thickness may be obtained.

The apparatus is placed on a stand,

and the value of the milk is estimated by the thickness of the layer of it through which the light of a small wax taper at a fixed distance (three feet) can be observed, the value of the milk being in the inverse ratio of the transparency; the larger the amount of fat present, the greater, of course, will be the opacity. The thickness of the layer of milk is measured by a scale on the instrument, and a table sold with it shows the percentage of cream to which it corresponds.*

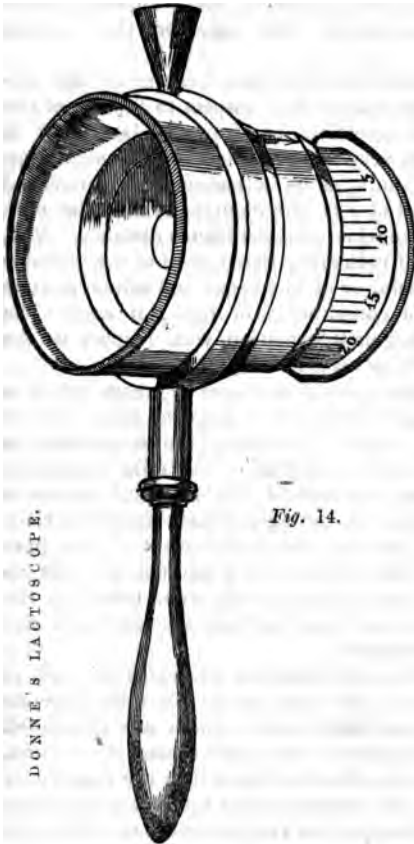


Fig. 14.

* A simple form of Lactoscope has been invented by Dr. Minchin of Dublin, which may be advantageously employed to measure the opacity of milk.

PART XIII.

ADULTERATION OF MILK.

It has been stated that in milk we have an article of food which affords a type of the aliment adapted for the nutrition of the young of the mammalia. It contains *casein*, the matter of the curd which supplies nitrogenized material required for building up the muscles and soft parts of the animal body, and which gives cheese its sustaining power as food. We also discover in it *phosphate of lime* and other mineral compounds, which enter into the composition of bone and blood, while its sugar and fatty matters serve for supporting respiration and animal heat, and, in certain conditions of the system, for the development of fat. Thus it is a mixture of the three classes of nutritive constituents, the nitrogenized or muscle-forming, the carbonaceous or respiratory, and the mineral or saline. In milk these nutritive substances exist, as lately described, partly in solution, and in part are merely suspended in water, the fatty matters being enclosed in thin bags or envelopes, which ascend to the surface of the liquid when it is allowed to remain at rest. By rupturing these bags, as is effected in the operation of churning, the fatty matter escapes, and its particles coalesce, so as to form butter.

The total amount of the different nutritive constituents contained in the milk of the cow, as well as the relative proportions of each, are, as is well known, influenced by a great many circumstances; these will require our consideration on a future occasion, but at present we will confine our remarks to the investigation of those unwarrantable interferences with the natural composition of this important fluid, which render the quality of that which is usually sold under the name of milk in our large towns frequently so much inferior in nutritive value to the ordinary produce of the country dairy.

The usual methods of ascertaining the quality of milk, I have shown cannot be relied upon in forming an opinion of its actual value. Thus its density, as deter-

mined by the hydrometer, cannot be taken as indicating correctly even its richness in cream, while neither that instrument nor the lactometer, affords us any information with respect to the amount of casein and sugar present. Both the lactometer and the French instrument, the *lactoscope*,* merely indicate the per centage of fatty matter which the milk contains, so that a sample of milk, rich both in curdy matter and sugar, but poor in butter, would, if we depended upon their indications, be pronounced as of very inferior quality; and, on the other hand, a sample of milk, though deficient both in cheese and sugar, but rich in butter, might, even though mixed with water, be regarded as of a superior description. Therefore, for the reasons just stated, as well as on account of the irregularity in the results which the ordinary milk gauge has been shown to afford when the milk has been brought from a distance, and of the various circumstances which interfere with its accuracy, its employment in the Workhouses of the country, as a "test" of the quality of milk, must be regarded as objectionable. How, then, you will inquire, are we to proceed—are there no means by which the farmer may correctly estimate the value of the milk supplied by his cows, or by which the purchaser, and especially public establishments, may be protected from fraudulent adulterations?

Fortunately, science is not so deficient in resources; and by combining together the use of the hydrometer and lactometer in the method that I shall describe, we may obtain a close approximation to the actual value of milk, sufficiently accurate for all practical purposes, and also be enabled to ascertain whether it has been diluted with water.

These methods consist—1st. In employing the hydrometer to measure the density of the sample of milk. 2nd. Of the lactometer to measure the per-centage of cream which the milk affords. 3rd. The estimation by the hydrometer of the density of a sample of milk from which the cream has been removed.

* This beautiful invention of Dr. Donné, was sometime ago exhibited to the members of the Chemico-Agricultural Society, on its first introduction to this country by the Author. It may be seen by those interested in the subject in the Agricultural Museum of Queen's College, Belfast, and in the admirably arranged dairy of the Albert Farm at Glasnevin.

The operations which require to be performed, are the following :—1st. About a pint of the milk should be taken from the pail into which the entire quantity drawn from the cows has been received. If the cream has begun to separate, it should be mixed up with the milk previous to taking the sample. Pour a portion of the milk into the lactometer, up to the line near the top at which the graduation commences, and place the remainder in a tall glass ; ascertain the temperature by a thermometer—in summer it will be most likely above, and in winter below 50 degrees. It must be brought to that temperature by placing it in a pan of warm or cold water as the case may require. When the proper temperature has been obtained, introduce the hydrometer, and observe the density indicated. The remaining portion of the milk, and also that which has been used in the examination of the specific gravity, are to be placed in a pan, and set aside for twelve hours. 2nd. When the milk in the lactometer has been allowed to remain at rest for twelve hours, note the per-centage of cream which has separated. 3rd. Carefully remove the cream which has formed on the milk set aside in the pan, and place the skim milk in the tall glass, bring it to the temperature of 50 degrees, and ascertain its density by the hydrometer. By these three observations we are furnished with the specific gravity of the whole milk, the proportion of cream which it contains, and the density of the solution of sugar and casein from which the greater portion of the fatty matter has separated. It is obvious that for the correct interpretation of the results obtained we must possess certain data with respect to the average density of whole and skimmed milk, and also the per-centage of cream which milk of average quality may be expected to afford. The following table, given in the reports on Food and its Adulterations, which have been published by Dr. Hassall, and which was drawn up in connexion with the investigations of the Sanitary Inquiry instituted by "*The Lancet*," in London, may be employed for this purpose. I have slightly altered the arrangement of the columns to facilitate reference. The first column, you will observe, shows the specific gravity of the whole milk as determined by the hydrometer ; the second column the specific gravity of the skim milk,

the third, the corresponding per-centage of water present, and the fourth, the amount of curd.*

Specific Gravity.	Skim Milk, Specific Gravity.	Per-centage of Water.	Grains of Curd.
1014	15	50	29
1017	18	40	35
1020	21	30	42
1023	25	20	50
1026	27	10	54
1029	30	Pure	61

So far as I can learn, water is the only adulterating substance employed in this part of Ireland by milk dealers; and though it is usually supposed that London milk contains a very small amount of the genuine article, and that in addition to the comparatively innocent dilution with water, various substances, as starch, gum, whiting, and even portions of the brains of animals are employed to give a rich appearance to it, yet Dr. Hassall did not detect any of these substances. That, however, cerebral matter has

* Table showing the specific gravity of pure milk, and the per-centages of cream:—

MORNING MILK.

	Cows.	Milk. Sp. Grav.	Cream.	Curd.	Yield per day.
Richmond,	1	1030	6½	63	14 qts.
	2	1031	7	69	7
Fed partly on grass and partly on grains.	3	1028	4½	66	13
	4	1030	9	80	10
	5	1031	10	78	8
	6	1028	7½	75	12
London, ..	7	1030	12	55	10
	8	1023	5	81	10
	9	1029	7	61	10
	10	1028	9	65	9
Average nearly,	..	1029	average about 7½		

AFTERNOON MILK.

	Cows.			
Richmond,	1	1028	7½	69
	2	1027	10	91
	3	1027	6	75
	4	1028	9	78
	5	1026	11½	87
	6	1027	7½	83
London, ..	7	1028	22	98
	8	1026	6	74
	9	1026	6	69
	10	1026	11	86
Average about	..	1027	average more than 9½	

been used, both in London and Paris, appears to be certain, both from the reports of Continental chemists, and the statement of some of the witnesses lately examined before the Parliamentary Committee. We have not, in our examinations in Belfast, discovered that any other adulteration than that of the "milk of the cow with the iron tail" has been made. The allowance of water is indeed very considerable, and sometimes retailers would seem to imitate the milk dealers of Paris, one of whom, a large contractor of the public establishments, is reported to have frankly remarked, at a time when the forage of cows had risen to a high price, that in common seasons "it was usual to put a little water to the milk, but at present they were obliged to put a little milk to the water." The disgusting addition of cerebral matter to milk, is fortunately easily detected by the microscope, which in this, as in many other cases, is capable of affording the chemist the most valuable assistance. When a drop of the suspected milk is placed on a slip of glass and examined, the nerve tubules, as shewn in the accompanying beautiful illustration from Dr. Hassall's treatise, can readily be detected.—

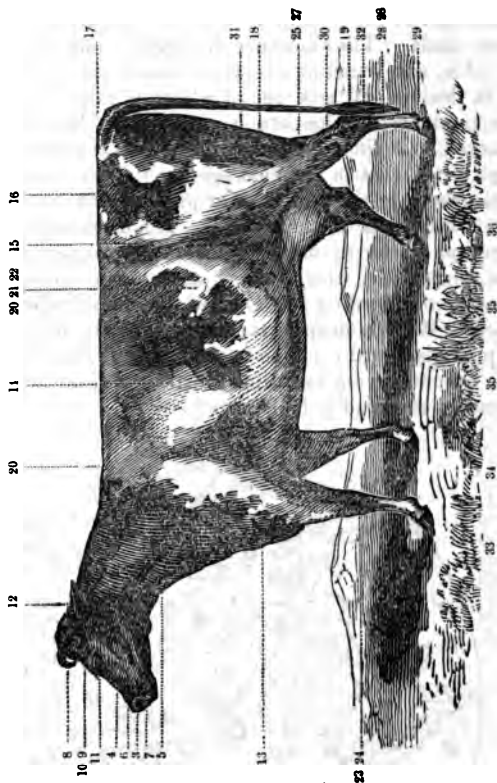


Fig. 15.

APPENDIX.

JERSEY COW.—PERFECTION, 36 POINTS.

PEDIGREE Nos. 1 AND 2.



**SCALE OF POINTS FOR COWS AND HEIFERS,
ADOPTED BY THE ROYAL JERSEY AGRICULTURAL SOCIETY.**

ARTICLE.	POINTS.
1. Pedigree on male side	1
2. Pedigree on female side	1
3. Head, small, fine, and tapering	1
4. Cheek, small	1
5. Throat, clean	1
6. Muzzle, fine and encircled with a light colour	1
7. Nostrils, high and open	1
8. Horns, crumpled, not too thick at the base, and tapering, tipped with black	1
9. Ears, small and thin	1
10. Ears, of a deep orange colour within	1
11. Eye, full and placid	1
12. Neck, straight, fine, and lightly placed on the shoulders	1
13. Chest, broad and deep	1
14. Barrel, hooped, broad and deep	1
15. Well-ribbed home, having but little space between the last rib and the hip	1
16. Back, straight from the withers to the top of the hip	1
17. Back, straight from the top of the hips to the setting on of the tail; and the tail at right angles with the back	1
18. Tail, fine	1
19. Tail, hanging down to the hocks	1
20. Hide, thin and moveable, but not too loose	1
21. Hide, covered with fine and soft hair	1
22. Hide, of a good colour	1
23. Fore-legs, short, straight, and fine	1
24. Fore-arm, swelling and full above the knee, and fine below it	1
25. Hind-quarters, from the hock to the point of the rump, long and well filled up	1
26. Hind-legs, short and straight (below the hocks), and bones rather fine	1
27. Hind-legs, squarely placed, not too close together when viewed from behind	1
28. Hind-legs, not to cross in walking	1
29. Hoofs, small	1
30. Udder, full in form, <i>i.e.</i> well in line with the belly	1
31. Udder, well up behind	1
32. Teats, large and squarely placed, being wide apart	1
33. Milk-veins, very prominent	1
34. Growth	1
35. General appearance	1
36. Condition	1
Perfection	36

No prize shall be awarded to a Cow having less than 29 points.

No prize shall be awarded to a Heifer having less than 26 points.

A Cow having obtained 27 points, and a Heifer 24 points, without pedigree, shall be allowed to be Branded, but cannot in either case take a prize.

Three points, viz. Nos. 30, 31, and 33, shall be deducted from the number required for perfection in Heifers, as the Udder and Milk-veins cannot be fully developed; a Heifer, therefore, will be considered to be perfect at 33 points.

The term "Pedigree" is employed to signify the offspring of a prize, or decorated Male or Female Stock.

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